INSTRUCTION MANUAL

Tenney
ENGINEERING, INC.

The Largest and Most Experienced Manufacturer of High Technology Environmental Test Equipment

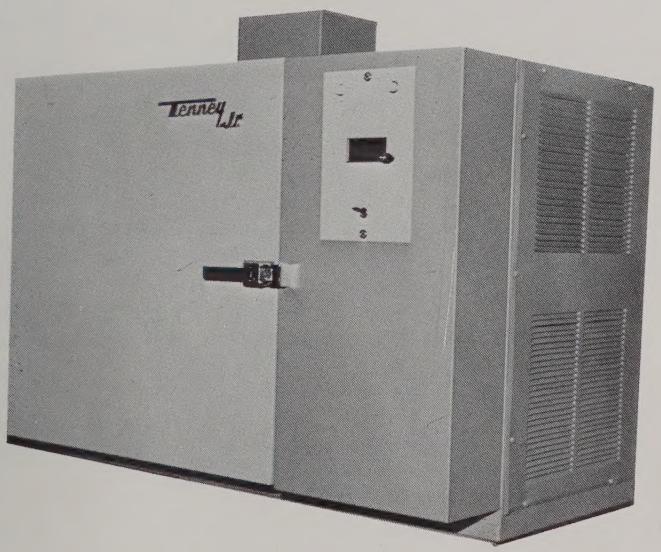
Tenney ENGINEERING, INC.

Bulletin #108S
Tenney Jr., 1¼ cubic foot
Benchtop Test Chamber

Benchtop Model

TENNEY JR.

High/Low Temperature Environmental Test Chamber



Workspace: 16"W x 12"H x 11"D
Temperature Range: −80°C to +200°C

The Tenney Jr. temperature benchtop test chamber offers outstanding performance, reliability and long life. It is the most popular environmental chamber on the market and is especially adaptable for laboratory use in product development, quality assurance, research, electronic and MIL-STD testing. Simplicity of design allows for virtually maintenance-free operation. It is completely self-contained and ready for immediate plug-in use.

The unit utilizes a dual compressor cascade mechanical refrigeration system. Sequential starting of compressors reduces starting current. Thus the system requires no CO_2 and is, therefore, free of the inconvenience and expense of this method. At the same time, the Tenney Jr. can achieve a temperature that is 6.7°C colder than that possible with CO_2, i.e. −80°C.

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1090 Springfield Rd., P.O. Box 3142, Union, New Jersey 07083 • (201) 686-7870

CONSTRUCTION

The Tenney Jr. uses heavy gauge, reinforced, heliarc welded stainless steel interior for strength and durability. The insulated enclosure is constructed with vapor weld walls for impermeability to moisture, and mass type fiberglass for low heat transfer.

The heavy gauge exterior offers an attractive, but tough, two-tone blue washable finish. Units feature a 2" (5 cm) diameter accessory port with plug insert, and a six-foot electrical power cord with grounded plug. All wiring connections are made at numbered terminal strips and are in accordance with NEC. Full opening lap-type door, with two concentric thermal gaskets for vapor-tight sealing, is provided. This door is hinged and removable, offering quick and easy loading and unloading.

STANDARD FEATURES

- Reads direct temperature and temperature setpoint on a 3½ digit LED display to 0.1°C.
- Temperature control circuits provide quick response to load demands, minimize oscillations that control to an accuracy of ±0.15°C throughout the complete chamber operating range.
- Solid state SCR, fast response, platinum resistance sensor temperature controller, that features automatic reset and proportioning control.
- RFI free instrument.
- Hermeticool® an accessible hermetic refrigeration system incorporating accurately calibrated capillary tubes in lieu of mechanical expansion valves.
- Nichrome heaters designed to provide rapid response to instrument demand.
- Pilot light indicates heater status on or off.
- High volume circulating fan provides uniformity of workspace environment.
- Tenney one-year warranty.

OPTIONAL FEATURES

- DigiTenn®, a push-button microprocessor programmer. Replaces cams and punched tape devices.
- IEEE-488 Bus Interface
- Two-point programming for temperature cycling
- Remote setpoint, 0-5 VDC
- Pressure gauges for refrigeration system
- TempGard® III temperature alarm system guards against out-of-tolerance temperatures in test chamber. Protects chamber and test specimen.
- Automatic CO_2 or LN_2 booster system
- Recording instruments
- Thermocouple or electrical terminals
- Special connectors
- Thermal pane viewing window, 6" x 8" (15cm x 20cm)
- Vapor-sealed interior light
- Adjustable stainless steel shelf
- Interchangeable doors
- Additional or larger ports
- Cart with casters

SPECIFICATIONS AND PERFORMANCE DATA

Heating Rates

+25°C to +100°C	15 minutes
+25°C to +150°C	30 minutes
+25°C to +200°C	55 minutes

Cooling Rates

+25°C to −40°C	20 minutes
+25°C to −54°C	30 minutes
+25°C to −65°C	40 minutes
+25°C to −73°C	55 minutes
+25°C to −80°C	65 minutes

Capacity for holding live load during temperature performance

−40°C	170 watts
−54°C	145 watts
−65°C	105 watts
−73°C	60 watts
−80°C	25 watts

Control of conditions is as indicated on instrumentation furnished with chamber. Minor performance variations with window and accessories. Performance data is based on ambient temperature of +24°C at sea level, on 60 Hertz operation. For 50 Hertz operation, performance will be approximately 17% less. Under certain programming conditions, stated rates of change may vary.

Temperature Range
−80°C to +200°C

Control Tolerance
±.15°C

Exterior Dimensions
36"W x 30½"H x 21"D
(91cm x 78cm x 53cm)

Interior Dimensions
16"W x 12"H x 11"D
(41cm x 31cm x 28cm)

Power Requirements
115-1-60 20 amp fuse recommended

Shipping Weight Uncrated (approx.)
260 lbs. (125kg)

Tenney Jr. chambers are also available on a direct lease basis.

In line with our policy of continual product improvement, Tenney Engineering, Inc. reserves the right to incorporate and use equipment and material to conform with the latest design of its products and in keeping with the specifications of this equipment.

Printed in U.S.A.

Made in our NJ Plant

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NOTICE

Before operating your new Tenney Jr., inspect the conditioner fan inside the chamber. This fan is driven by a shock-mounted motor on top of the cabinet. Occasionally, during shipment, the motor is pushed out of vertical alignment. As a consequence, the fan blades will strike the casing. The cure is to push the fan motor back into proper alignment on its rubber mounts.

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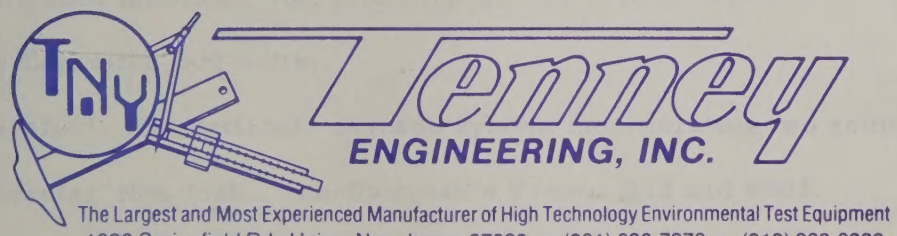

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TENNEY JR. INSTRUCTIONS

Introduction

This manual covers installation, operation, servicing and trouble-shooting of your new Tenney Jr. environmental test facility.

About The Tenney Jr.

Your new Tenney Jr. is a precision, compact, versatile test equipment having the work chamber automatically maintained at selected high or low temperatures between -112°F and +392°F., (-80°C and +200°C). The appliance is completely self-contained and semi-portable. Its precise temperature regulation makes the Tenney Jr. ideal for testing small components. But it is equally well suited as a production facility and, in fact, is excellent for any application requiring carefully controlled temperatures in a confined volume.

Specifications

Overall dimensions: 36" wide; 30-1/4" high; 21" deep.

Workspace: 16" wide; 12" high; 11" deep.

Approximate Weight: 200 pounds.

Operating Range: -112°F to +350°F. (-80° C to +177°C)

Control Tolerance: ±1/4°F.

Recommended Ambient: +60°F to +100°F. (16°C to 38°C).

Heating Capacity: 500 watts.

Refrigeration: Hermeticool, cascade system incorporating two compressors.

Refrigerants: Non-toxic, non-flammable Freon, R12 and R503.

Power Required: 115 volts 60 cycle or 100 volts 50 cycle; single phase, 18 amps, at max. operation

Fuse Recommended: 20 ampere slo-blow in main power line.

Heat Limiter: Busman #WKV in heater circuit. Don't shunt this or replace it with an ordinary fuse.

Temperature Controller: TNNY-JRCO-0001

Timer: Two-point program models use Tork Timer E104.1.3.

Air Circulation: By vertical shaft fan and 1/50 hp Micro Motor, Redmond AK2H02A or equivalent.

Putting The Chamber Into Operation

Your Tenney Jr. has been completely assembled and carefully tested; it is ready to plug in and use. Place the appliance where ventilation is good and leave at least a foot of space between the cabinet's right side and the wall. Remember, the condenser is air cooled and must have fresh air if the refrigeration system is to operate efficiently.

Leave room for the door to swing clear. It is hinged left and swings on pin type hinges. To remove the door, just open it and lift; you may then fit it with any special door-mounted accessories you like. Standard doors are blank; but special doors having ports, feed-throughs or windows are available from Tenney Engineering.

Specified performance is predicated on the facility being located in a room where the ambient temperature is between +60°F and +100°F (16°C and 38°C). The unit may be operated in ambients outside that range but cooling and heating capacity and transient rates will be altered proportionately.

Once the equipment is plugged into a 115 volt power source, is given adequate ventilation, and is reasonably level, it is ready for use.

Please note that while the Tenney Jr. operates on 115 volt AC "household" current, its ampere demand is higher than that of most household appliances. Your chamber must be wired to a service capable of handling high starting inrush current to the refrigeration compressors. Voltage drop must be minimal to assure reliable performance.

We urge that you operate the T-Jr. on a separate line of its own, wired directly to your junction box. Wiring size must be #12 gauge AWG or heavier; fusing should be 20 ampere slo-blow or twenty ampere circuit breaker.

An important point! If you must use an extension cord, use a heavy one - not lighter than 12 gauge wire. Stringy extensions are an enemy of good Tenney Jr. performance and may even damage the refrigeration compressors.

How To Use Your Tenney Jr.

The machine is simple to operate. To simulate temperatures above about +110°F (43°C), simply press in on the setpoint knob under the digital display. Turn the knob, while pressing, until the desired temperature appears on the display. Release the knob. Throw the mode selecting switch to HEAT.

To simulate temperatures below about +110°F (43°C), press the setpoint knob; select desired temperature; throw the mode switch to COOL.

Note: When the mode switch is in the HEAT position, heating alone is available to the controller. But when the switch is thrown to COOL, both reduced heat and refrigeration will respond to controller commands.

Operating Hints

1. Under certain load conditions, you may notice a slight difference between chamber temperature and the selected setpoint. If this happens, re-adjust the setpoint selector until the digital thermometer reports the desired temperature. Make the adjustment slowly: The offset is not necessarily linear and you must allow several minutes between each small adjustment for the equipment to stabilize.

2. When changing to a considerably higher test temperature, operate in HEAT mode regardless of the desired test temperature. This will decrease required heat-up time.

3. If you have been operating below +40°F (4°C), heat the chamber to room temperature or a little higher before shutdown. This will prevent ambient moisture from migrating to the chamber when the door is opened. Condensing or frosting is prevented.

4. Despite being equipped with a high accuracy control instrument, it is possible for this facility to overshoot in temperature under extreme conditions. When adjusting the selector from very low to very high heat, set the selector roughly 15°F (9°C) low. Allow a few minutes for stabilization, then raise the setting to the finally desired high test temperature.

Controls And Indicators

Setpoint Selector: When pressed in, the temperature setpoint knob selects desired chamber temperature.

Mode Selector Switch: Three positions are offered by this switch. Center is off. Heat selection arms the temperature controller, arms 500 watts of heat, energizes both the conditioner fan and the condenser fan.

Cool selection performs the same functions as heat selection. However, this selection cuts heating power in half and also energizes the refrigeration compressors sequentially. The R12 high stage compressor is energized directly by the switch; then the R503 compressor is brought on the line by a pressure switch activated by the high stage. The arrangement prevents both machines "hitting" the power line simultaneously.

Chamber Temperature Indicator: The LED digital thermometer indicates temperature in the air stream near the conditioner, and has a quick response time.

Power Pilot Light PL1: When the mode selector switch is thrown to either position, the power-on light glows.

Control Pilot Light: This pilot light glows when the controller is signaling for heat. Relatively regular pulsing of the light indicates that the chamber is operating at or close to setpoint temperature.

About The Temperature Controller

The precise temperature controller used on your Tenney Jr. is all solid state. Silicon controlled rectifiers and transistors replace all relays and moving parts in this reliable controller.

Time proportioning action is used. Output is cycled from "on" to "off" and back again on a fixed time cycle but the percentage of "on" time is varied as required to hold temperature steady at the desired value. The controller switches directly from heating to cooling and vice versa. When the controller calls for heat, it applies power directly to the resistance heater. When it calls for cooling, it deenergizes a solenoid bypass (artificial loading) valve and allows refrigerant to flow through the cooling coils.

Caution: Many oscilloscopes and AC powered voltmeters have one terminal grounded. Do not attempt to measure controller output with this kind of instrument. A crossed-ground might cause a short circuit which would permanently damage the controller.

PREVENTIVE MAINTENANCE

In addition to ordinary cleaning, oiling of hardware and general housekeeping maintenance, we suggest a few simple, periodic preventive maintenance routines:

The refrigeration compressors are hermetically sealed, internally sprung and are not serviceable. However, examine them occasionally to be sure they are well secured to the machinery frame and that vibration has not chafed pressure or suction lines. Be sure the starting capacitor, relay and thermal overload protector are firmly clipped in place on the hermetic unit.

Once or twice a year clean the condenser coil with a vacuum cleaner brush. Frequency of cleaning depends, naturally, on dustiness of location. To get at the coil, remove the right panel.

About every 300 hours of operation, put a drop of oil in each oil cup on the conditioner fan motor. This is the vertical motor that drives the chamber fan. Lubricate with SAE #20 oil.

Several times a year, or as required, clean the inside of the chamber. Carefully clean the blades of the air circulating fan. Tenney's Humiclean mixed with water is an excellent general metal cleaner for use in all environmental chamb ers. It is available from our service department. (Unplug the chamber when performing preventive maintenance.)

In Case of Trouble

Be careful! The Tenney Jr. has wires carrying 115 volts with heavy current carrying capacity. Unplug the unit from the electrical power supply before making trouble-shooting tests. The HEAT/COOLING switch, when centered, disables the conditioning equipment but does not remove voltage from across the main line. This circuit remains hot.

A list of possible malfunctions, their symptoms, principal cause and remedy are found in the trouble shooting chart which follows.

Components of the refrigeration system are included in the trouble chart to assist you in pinpointing malfunctions. But don't attempt to repair sealed portions of the refrigeration system: This should be done by Tenney Engineering only. However, the Hermeticool refrigeration system is highly reliable and fully ninety percent of all troubles will develop outside of the sealed portion. Controls, fans, wiring, capacitors, are more likely to give trouble than sealed compressors.

A good ohmmeter is a great help in shooting trouble on the electrical and control system. The use of an ohmmeter and reference to the schematic drawing included with this manual should help you locate difficulties.

The following Chart II is a tabulation of more important "normal" resistances measured on new equipment at room temperature. Remember, though, that resistances vary considerably from item to item and ohmmeters deviate from one instrument to another. Use the table of values as a guide, realizing that moderate variations do not necessarily indicate trouble.

CHART II

Item	Measurement	Resistance
Compressor (either)	Common term to Start	4.8 ohms
Compressor (either)	Common term to Run	1 ohm
Compressor (either)	Common term to frame	Infinite
Conditioner fan motor	Across terminals	20 ohms
Heater element HTR1	HL to 3	55 ohms
Heater element HTR2	HL to 4	55 ohms
Solenoid valve	Across coil	80 ohms
Temperature sensor	Across terminals	100 ohms
Condenser fan motor	Across terminals	37 ohms

Satisfactory refrigeration performance depends on good line voltage at all times. Incoming power lines should be heavy enough that voltage never drops below 104 volts measured close to the compressor motor terminals, even when the compressor motors are thrown across the line. If the compressors seem to struggle when starting, measure this important voltage.

Note: Terminal arrangement on the Copeland compressor units is as follows: There are 3 terminals. Center top one (12 o'clock position) is common. Going clockwise to the 4 o'clock position is the run winding terminal. Around to the 8 o'clock position is the start winding terminal. All are insulated from ground.

Current Demand

Typical current draw measured with a snap-on type probe ammeter on the power cord with the chamber at -50°F (-46°C) and the refrigeration system operating fully, is about 14 amperes. Typical current with the mode selector switch on "Heat" and the heaters energized (compressors off) is about 4.5 amperes.

TROUBLE SHOOTING CHART

Complaint	Possible Cause	Action
No heat	Open heat limiter.	Test with meter, replace.
	Open heater element.	Inspect, test with meter, replace.
Compressor will not start and there is no hum.	Line disconnect switch open.	Close switch.
	Overload protector has tripped.	Wait 5 minutes. If overload does not close, replace.
	Broken wire.	Inspect, repair.

Complaint	Possible Cause	Action
Compressor hums but will not start.	Low supply voltage.	Get heavier service or heavier extension.
	Starting capacitor is defective.	Replace.
	Relay failing to operate.	Inspect, replace.
	Internal compressor trouble.	Measure winding resistances, test for grounds, write or call Tenney before returning unit.
Compressor starts, hums, runs slowly, stays on start winding.	Low line voltage.	Get heavier service.
	Stuck relay.	Replace.
	Shorted winding.	Test resistance, test for grounds. Notify Tenney.
Compressor runs but cools inefficiently.	Restricted ventilation, dirty condenser fins.	Move unit away from wall. Clean condenser coils.
Refrigeration system works long or continuously. (Heat light never glows.)	Excessive heat load.	Reduce load if possible.
	Evaporator coil iced.	Defrost.
	Dirty condenser.	Clean.

Complaint	Possible Cause	Action
Chronic shorting or blowing of start capacitors.	Sluggish relay.	Clean contact or replace relay.
	Excessive start time due to low voltage, improper relay.	Correct low voltage trouble, install correct relay.
	Improper capacitor.	Consult with Tenney and obtain correct capacitor.
Unit runs well but there is minimum chilling of evaporator coils.	Solenoid valve (artificial loading) stuck open.	Check with Tenney regarding replacement.
Noisy compressor.	Compressor loose on mounts.	Tighten hold downs.

Replacement Parts

There are no special procedures to replacing any of the unit's components. All parts are accessible after panels are removed. Note that while the hermetically sealed refrigeration system must not be opened, the coil in the artificial loading solenoid valve may be replaced without disturbing the soldered tubing.

When ordering parts or writing about your Tenney Jr., please state the serial number of your unit; It is stamped on the rating plate to the rear of the cabinet.

When writing about the refrigeration system, please supply chamber serial number. This information will help us identify your unit exactly.

Circuit Description

Knowledge of how the machine functions helps the user intelligently operate and maintain his Tenney Jr. With this thought in mind, we present here a simplified description of the electrical system. Please refer to the electrical schematic drawing while reading this.

Air Circulation

When mode switch SW1 is thrown to either heat or cooling, its upper pole, schematically, makes a circuit across the power line for the conditioner fan motor. As long as the switch is closed to either position, the fan continues to run, pilot light PL1 remains lit and the condenser fan runs.

Air Heating

Both nichrome air heaers AH1 and AH2 will be energized by temperature controller C1 when the mode switch is thrown to HEAT. Only heater AH1 can be energized when the switch is thrown to cooling.

Assume the mode switch is closed to the HEAT position. Also assume that workspace temperature is below setpoint and the controller is signaling for heat.

Through the upper pole (schematically) the mode switch makes a circuit to the temperature controller C1 and to the left terminal of heater AH1. Through the middle pole, the switch makes a connection to the left terminal of heater AH2. The temperature controller then completes the heater circuit by applying timed pulses of line power.

Next, imagine that the mode switch is thrown to cooling, but workspace temperature is below setpoint and the controller is calling for heat.

Circuits are the same as in the previous paragraph except that the mode switch center pole is down and AH2 is disabled. Reduced heating is through heater element AH1. Note also, that as a pulse of power is applied to the heater, voltage is applied to artificial loading valve SV. More about this valve in a moment.

Air Cooling

Cooling, through refrigeration, can only take place when the mode switch is in cooling position. When the mode switch is thrown to cooling, control circuits are set as follows:

The upper pole (on the schematic) lights pilot light PL1. It energizes the conditioner fan and condenser fan motors, arms the controller and half the heater bank.

Mode switch SW1 middle pole arms the artificial loading valve SV through pressure switch PS1.

The bottom pole (on the schematic) energizes the R12 compressor. Soon after the R12 compressor starts, cut-in switch PS2 detects reduced pressure in the R12 compressor suction line and starts the R-503 compressor. Typical cut-in pressure is 18 psig and cut-out about 30 psig.

The compressors remain locked on for all normal operation. They are not cycled for temperature control.

Artificial loading valve SV controls refrigeration capacity. When chamber temperature rises above setpoint, the controller breaks the circuit to the artificial loading valve. The valve closes, and a full flow of refrigerant is directed to the evaporator coils in the conditioner.

The artificial loading valve SV is a shunting or short circuiting valve that effectively reduces refrigeration capacity even though the compressors continue to run.

When refrigeration demand is satisfied, the controller opens valve SV, simultaneously making a circuit to heater AH1. Thus, by cycling between heating and cooling, the controller holds workspace temperature within close limits.

Pressure switch PS1, mentioned earlier, is a pressure actuated switch normally placing the artificial loading valve under temperature controller command. When pressure switch PS1 detects pre-determined high pressure in the low stage, it removes the artificial loading valve from temperature controller command. Then, by energizing the valve directly across the 115 volt line, switch PS1 holds the loading valve open regardless of controller commands. The loading valve continues to be held open until head pressure falls to the pressure switch setpoint.

Danger:

The machinery compartment has exposed connections.

Note:
THIS IS NOT AN EXPLOSION PROOF CHAMBER. Test items which might possibly give off explosive vapors must not be tested in this chamber.

MINCO

RESISTANCE TEMPERATURE TABLE
U.S. INDUSTRIAL SPEC. $R_{100C}/R_{0C} = 1.3911$
PLATINUM RESISTANCE THERMOMETER
100 OHMS AT 0°C.

TABLE 11-100

7300 Commerce Lane | Minneapolis, Minnesota 55432 | TWX: 910-576-2848 | Telephone : (612) 786-3121

T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)
-200.0	17.26	-155.0	36.67	-110.0	55.51	-65.0	73.93
-199.0	17.70	-154.0	37.09	-109.0	55.93	-64.0	74.34
-198.0	18.14	-153.0	37.52	-108.0	56.34	-63.0	74.74
-197.0	18.58	-152.0	37.94	-107.0	56.75	-62.0	75.15
-196.0	19.01	-151.0	38.37	-106.0	57.17	-61.0	75.55
-195.0	19.45	-150.0	38.79	-105.0	57.58	-60.0	75.96
-194.0	19.89	-149.0	39.21	-104.0	57.99	-59.0	76.36
-193.0	20.32	-148.0	39.63	-103.0	58.40	-58.0	76.77
-192.0	20.76	-147.0	40.06	-102.0	58.81	-57.0	77.17
-191.0	21.20	-146.0	40.48	-101.0	59.23	-56.0	77.58
-190.0	21.63	-145.0	40.90	-100.0	59.64	-55.0	77.98
-189.0	22.07	-144.0	41.32	-99.0	60.05	-54.0	78.39
-188.0	22.50	-143.0	41.74	-98.0	60.46	-53.0	78.79
-187.0	22.94	-142.0	42.16	-97.0	60.87	-52.0	79.19
-186.0	23.37	-141.0	42.59	-96.0	61.28	-51.0	79.60
-185.0	23.80	-140.0	43.01	-95.0	61.69	-50.0	80.00
-184.0	24.24	-139.0	43.43	-94.0	62.10	-49.0	80.40
-183.0	24.67	-138.0	43.85	-93.0	62.51	-48.0	80.81
-182.0	25.10	-137.0	44.27	-92.0	62.92	-47.0	81.21
-181.0	25.54	-136.0	44.69	-91.0	63.33	-46.0	81.61
-180.0	25.97	-135.0	45.10	-90.0	63.74	-45.0	82.01
-179.0	26.40	-134.0	45.52	-89.0	64.15	-44.0	82.42
-178.0	26.83	-133.0	45.94	-88.0	64.56	-43.0	82.82
-177.0	27.26	-132.0	46.36	-87.0	64.97	-42.0	83.22
-176.0	27.69	-131.0	46.78	-86.0	65.38	-41.0	83.62
-175.0	28.12	-130.0	47.20	-85.0	65.79	-40.0	84.03
-174.0	28.55	-129.0	47.62	-84.0	66.20	-39.0	84.43
-173.0	28.98	-128.0	48.03	-83.0	66.61	-38.0	84.83
-172.0	29.41	-127.0	48.45	-82.0	67.02	-37.0	85.23
-171.0	29.84	-126.0	48.87	-81.0	67.42	-36.0	85.63
-170.0	30.27	-125.0	49.28	-80.0	67.83	-35.0	86.03
-169.0	30.70	-124.0	49.70	-79.0	68.24	-34.0	86.43
-168.0	31.13	-123.0	50.12	-78.0	68.65	-33.0	86.84
-167.0	31.56	-122.0	50.53	-77.0	69.06	-32.0	87.24
-166.0	31.98	-121.0	50.95	-76.0	69.46	-31.0	87.64
-165.0	32.41	-120.0	51.37	-75.0	69.87	-30.0	88.04
-164.0	32.84	-119.0	51.78	-74.0	70.28	-29.0	88.44
-163.0	33.27	-118.0	52.20	-73.0	70.68	-28.0	88.84
-162.0	33.69	-117.0	52.61	-72.0	71.09	-27.0	89.24
-161.0	34.12	-116.0	53.03	-71.0	71.50	-26.0	89.64
-160.0	34.54	-115.0	53.44	-70.0	71.90	-25.0	90.04
-159.0	34.97	-114.0	53.86	-69.0	72.31	-24.0	90.44
-158.0	35.40	-113.0	54.27	-68.0	72.72	-23.0	90.84
-157.0	35.82	-112.0	54.68	-67.0	73.12	-22.0	91.24
-156.0	36.25	-111.0	55.10	-66.0	73.53	-21.0	91.64

T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)
-20.0	92.04	25.0	109.89	70.0	127.50	115.0	144.87
-19.0	92.44	26.0	110.28	71.0	127.89	116.0	145.26
-18.0	92.84	27.0	110.67	72.0	128.28	117.0	145.64
-17.0	93.24	28.0	111.07	73.0	128.66	118.0	146.02
-16.0	93.63	29.0	111.46	74.0	129.05	119.0	146.41
-15.0	94.03	30.0	111.86	75.0	129.44	120.0	146.79
-14.0	94.43	31.0	112.25	76.0	129.83	121.0	147.17
-13.0	94.83	32.0	112.64	77.0	130.22	122.0	147.55
-12.0	95.23	33.0	113.03	78.0	130.60	123.0	147.94
-11.0	95.63	34.0	113.43	79.0	130.99	124.0	148.32
-10.0	96.02	35.0	113.82	80.0	131.38	125.0	148.70
-9.0	96.42	36.0	114.21	81.0	131.77	126.0	149.08
-8.0	96.82	37.0	114.61	82.0	132.15	127.0	149.47
-7.0	97.22	38.0	115.00	83.0	132.54	128.0	149.85
-6.0	97.62	39.0	115.39	84.0	132.93	129.0	150.23
-5.0	98.01	40.0	115.78	85.0	133.32	130.0	150.61
-4.0	98.41	41.0	116.18	86.0	133.70	131.0	150.99
-3.0	98.81	42.0	116.57	87.0	134.09	132.0	151.37
-2.0	99.21	43.0	116.96	88.0	134.48	133.0	151.76
-1.0	99.60	44.0	117.35	89.0	134.86	134.0	152.14
0.0	100.00	45.0	117.74	90.0	135.25	135.0	152.52
1.0	100.40	46.0	118.13	91.0	135.64	136.0	152.90
2.0	100.79	47.0	118.53	92.0	136.02	137.0	153.28
3.0	101.19	48.0	118.92	93.0	136.41	138.0	153.66
4.0	101.59	49.0	119.31	94.0	136.79	139.0	154.04
5.0	101.98	50.0	119.70	95.0	137.18	140.0	154.42
6.0	102.38	51.0	120.09	96.0	137.57	141.0	154.80
7.0	102.78	52.0	120.48	97.0	137.95	142.0	155.18
8.0	103.17	53.0	120.87	98.0	138.34	143.0	155.56
9.0	103.57	54.0	121.26	99.0	138.72	144.0	155.94
10.0	103.96	55.0	121.65	100.0	139.11	145.0	156.32
11.0	104.36	56.0	122.04	101.0	139.49	146.0	156.70
12.0	104.75	57.0	122.43	102.0	139.88	147.0	157.08
13.0	105.15	58.0	122.82	103.0	140.26	148.0	157.46
14.0	105.55	59.0	123.21	104.0	140.65	149.0	157.84
15.0	105.94	60.0	123.60	105.0	141.03	150.0	158.22
16.0	106.34	61.0	123.99	106.0	141.42	151.0	158.60
17.0	106.73	62.0	124.38	107.0	141.80	152.0	158.98
18.0	107.13	63.0	124.77	108.0	142.19	153.0	159.36
19.0	107.52	64.0	125.16	109.0	142.57	154.0	159.74
20.0	107.92	65.0	125.55	110.0	142.95	155.0	160.12
21.0	108.31	66.0	125.94	111.0	143.34	156.0	160.50
22.0	108.70	67.0	126.33	112.0	143.72	157.0	160.87
23.0	109.10	68.0	126.72	113.0	144.11	158.0	161.25
24.0	109.49	69.0	127.11	114.0	144.49	159.0	161.63

T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)
160.0	162.01	205.0	178.91	250.0	195.57	295.0	212.00
161.0	162.39	206.0	179.28	251.0	195.94	296.0	212.36
162.0	162.77	207.0	179.66	252.0	196.31	297.0	212.73
163.0	163.14	208.0	180.03	253.0	196.68	298.0	213.09
164.0	163.52	209.0	180.40	254.0	197.04	299.0	213.45
165.0	163.90	210.0	180.77	255.0	197.41	300.0	213.81
166.0	164.28	211.0	181.15	256.0	197.78	301.0	214.17
167.0	164.65	212.0	181.52	257.0	198.15	302.0	214.54
168.0	165.03	213.0	181.89	258.0	198.51	303.0	214.90
169.0	165.41	214.0	182.26	259.0	198.88	304.0	215.26
170.0	165.79	215.0	182.63	260.0	199.25	305.0	215.62
171.0	166.16	216.0	183.01	261.0	199.61	306.0	215.98
172.0	166.54	217.0	183.38	262.0	199.98	307.0	216.34
173.0	166.92	218.0	183.75	263.0	200.34	308.0	216.70
174.0	167.29	219.0	184.12	264.0	200.71	309.0	217.06
175.0	167.67	220.0	184.49	265.0	201.08	310.0	217.42
176.0	168.05	221.0	184.86	266.0	201.44	311.0	217.79
177.0	168.42	222.0	185.23	267.0	201.81	312.0	218.15
178.0	168.80	223.0	185.60	268.0	202.17	313.0	218.51
179.0	169.17	224.0	185.98	269.0	202.54	314.0	218.87
180.0	169.55	225.0	186.35	270.0	202.90	315.0	219.23
181.0	169.93	226.0	186.72	271.0	203.27	316.0	219.59
182.0	170.30	227.0	187.09	272.0	203.64	317.0	219.95
183.0	170.68	228.0	187.46	273.0	204.00	318.0	220.31
184.0	171.05	229.0	187.83	274.0	204.37	319.0	220.67
185.0	171.43	230.0	188.20	275.0	204.73	320.0	221.03
186.0	171.80	231.0	188.57	276.0	205.09	321.0	221.38
187.0	172.18	232.0	188.94	277.0	205.46	322.0	221.74
188.0	172.55	233.0	189.31	278.0	205.82	323.0	222.10
189.0	172.93	234.0	189.68	279.0	206.19	324.0	222.46
190.0	173.30	235.0	190.05	280.0	206.55	325.0	222.82
191.0	173.68	236.0	190.42	281.0	206.92	326.0	223.18
192.0	174.05	237.0	190.78	282.0	207.28	327.0	223.54
193.0	174.43	238.0	191.15	283.0	207.64	328.0	223.90
194.0	174.80	239.0	191.52	284.0	208.01	329.0	224.26
195.0	175.18	240.0	191.89	285.0	208.37	330.0	224.61
196.0	175.55	241.0	192.26	286.0	208.74	331.0	224.97
197.0	175.92	242.0	192.63	287.0	209.10	332.0	225.33
198.0	176.30	243.0	193.00	288.0	209.46	333.0	225.69
199.0	176.67	244.0	193.37	289.0	209.82	334.0	226.05
200.0	177.04	245.0	193.73	290.0	210.19	335.0	226.40
201.0	177.42	246.0	194.10	291.0	210.55	336.0	226.76
202.0	177.79	247.0	194.47	292.0	210.91	337.0	227.12
203.0	178.16	248.0	194.84	293.0	211.28	338.0	227.48
204.0	178.54	249.0	195.21	294.0	211.64	339.0	227.83

T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)
340.0	228.19	385.0	244.14	430.0	259.86	475.0	275.34
341.0	228.55	386.0	244.50	431.0	260.21	476.0	275.68
342.0	228.91	387.0	244.85	432.0	260.55	477.0	276.02
343.0	229.26	388.0	245.20	433.0	260.90	478.0	276.36
344.0	229.62	389.0	245.55	434.0	261.25	479.0	276.70
345.0	229.98	390.0	245.90	435.0	261.59	480.0	277.05
346.0	230.33	391.0	246.25	436.0	261.94	481.0	277.39
347.0	230.69	392.0	246.60	437.0	262.28	482.0	277.73
348.0	231.04	393.0	246.96	438.0	262.63	483.0	278.07
349.0	231.40	394.0	247.31	439.0	262.98	484.0	278.41
350.0	231.76	395.0	247.66	440.0	263.32	485.0	278.75
351.0	232.11	396.0	248.01	441.0	263.67	486.0	279.09
352.0	232.47	397.0	248.36	442.0	264.01	487.0	279.43
353.0	232.82	398.0	248.71	443.0	264.36	488.0	279.77
354.0	233.18	399.0	249.06	444.0	264.70	489.0	280.11
355.0	233.54	400.0	249.41	445.0	265.05	490.0	280.45
356.0	233.89	401.0	249.76	446.0	265.39	491.0	280.79
357.0	234.25	402.0	250.11	447.0	265.74	492.0	281.13
358.0	234.60	403.0	250.46	448.0	266.08	493.0	281.47
359.0	234.96	404.0	250.81	449.0	266.43	494.0	281.80
360.0	235.31	405.0	251.16	450.0	266.77	495.0	282.14
361.0	235.67	406.0	251.51	451.0	267.11	496.0	282.48
362.0	236.02	407.0	251.86	452.0	267.46	497.0	282.82
363.0	236.37	408.0	252.21	453.0	267.80	498.0	283.16
364.0	236.73	409.0	252.56	454.0	268.15	499.0	283.50
365.0	237.08	410.0	252.90	455.0	268.49	500.0	283.84
366.0	237.44	411.0	253.25	456.0	268.83	501.0	284.18
367.0	237.79	412.0	253.60	457.0	269.18	502.0	284.51
368.0	238.15	413.0	253.95	458.0	269.52	503.0	284.85
369.0	238.50	414.0	254.30	459.0	269.86	504.0	285.19
370.0	238.85	415.0	254.65	460.0	270.21	505.0	285.53
371.0	239.21	416.0	255.00	461.0	270.55	506.0	285.87
372.0	239.56	417.0	255.34	462.0	270.89	507.0	286.20
373.0	239.91	418.0	255.69	463.0	271.24	508.0	286.54
374.0	240.27	419.0	256.04	464.0	271.58	509.0	286.88
375.0	240.62	420.0	256.39	465.0	271.92	510.0	287.22
376.0	240.97	421.0	256.74	466.0	272.26	511.0	287.55
377.0	241.33	422.0	257.08	467.0	272.61	512.0	287.89
378.0	241.68	423.0	257.43	468.0	272.95	513.0	288.23
379.0	242.03	424.0	257.78	469.0	273.29	514.0	288.56
380.0	242.38	425.0	258.13	470.0	273.63	515.0	288.90
381.0	242.74	426.0	258.47	471.0	273.97	516.0	289.24
382.0	243.09	427.0	258.82	472.0	274.32	517.0	289.57
383.0	243.44	428.0	259.17	473.0	274.66	518.0	289.91
384.0	243.79	429.0	259.51	474.0	275.00	519.0	290.25

DATA SHEET - TENNEY ENGINEER

MODEL: TNNY-JRCO-0001
TEMPERATURE CONTROLLE

11-18-83 LDB

GENERAL: The Model No. TNNY-JRCO-0001 Temperature Controller has a 3-1/2 digit L.E.D. display and a push-to-set and read set point mechanism. The control is constructed for behind-the-panel mounting.

SPECIFICATIONS:

A.C. Power: 115V/230V, 50/60 Hz., ± 15% line variations.

A.C. Power Consumption: Less than 6 V.A.

Set Point Range: -99.9°C to +199.9°C

Indication: The indicator reads from -99.9 to +199.9. An open and shorted sensor is indicated by only the four decimal points (.) lighted preceded by minus (-) if shorted.

Signal Conditioner: The control system uses a 100 ohm platinum sensor and the signal conditioner linearizes the signal over the range of -99°C to +200°C. The accuracy is ± 1°C.

Analog Signal: This output, available on the terminal marked $+E_S$, is a linearized output voltage and can be used for driving a chart recorder, etc. It is scaled at 2.5 millivolts per L.S.D. and ranges between -2.5 volts to 5.0 volts for the temperature range -99.9°C to +199.9°C.

Programmer Input: The input terminals labeled P+ and P- accept a linear input D.C. voltage of 0 to 5 volts for temperature programming. Zero volts input equals -99.9°C and 5 volts input generates a set point of +199.9°C.

When using this input, remove jumper wire between terminals labeled P_2 and P+.

Control Mode: Time proportioning with auto reset.

Proportional Band: Adjustable over the range of 4 to 40°C.

Auto Reset: Time constant adjustable over the range of 35 seconds to 15 minutes. Error signal from control equals 1 volt.

Output: A zero crossing gate signal to turn external triac on at the zero voltage line crossing of the load voltage.

11-18-83 LDB

Cycle Time: 4 seconds minimum at 50% duty cycle.

Output Terminals: Output terminals for the (L_1) line for the heater load and one side of the heater are provided. Terminals labeled T_2, G, and T_1 connect to corresponding terminals on external triac.

Output Protection: Transient protection for the external triac is provided on the controller circuit board.

Null Meter Output: A current output for driving an external null meter is provided. This output is available on terminals labeled M+ and M-. Nominal sensitivity is (-500 μA) - 0 - (+500 μA). Full scale (500 μA) in each polarity represents 5°C.

BCD Output: A multiplexed BCD output is available to indicate temperature and polarity to the nearest 1/10 degree. This output is available on a 12 pin ribbon cable-header. See attached chart for functional designations of the individual pins on this connector.

Sensor: The temperature sensor is 100 ohm @ 0°C platinum element.

R_t = 59.59 ohms @ -100°C

R_t = 100 ohms @ 0°C

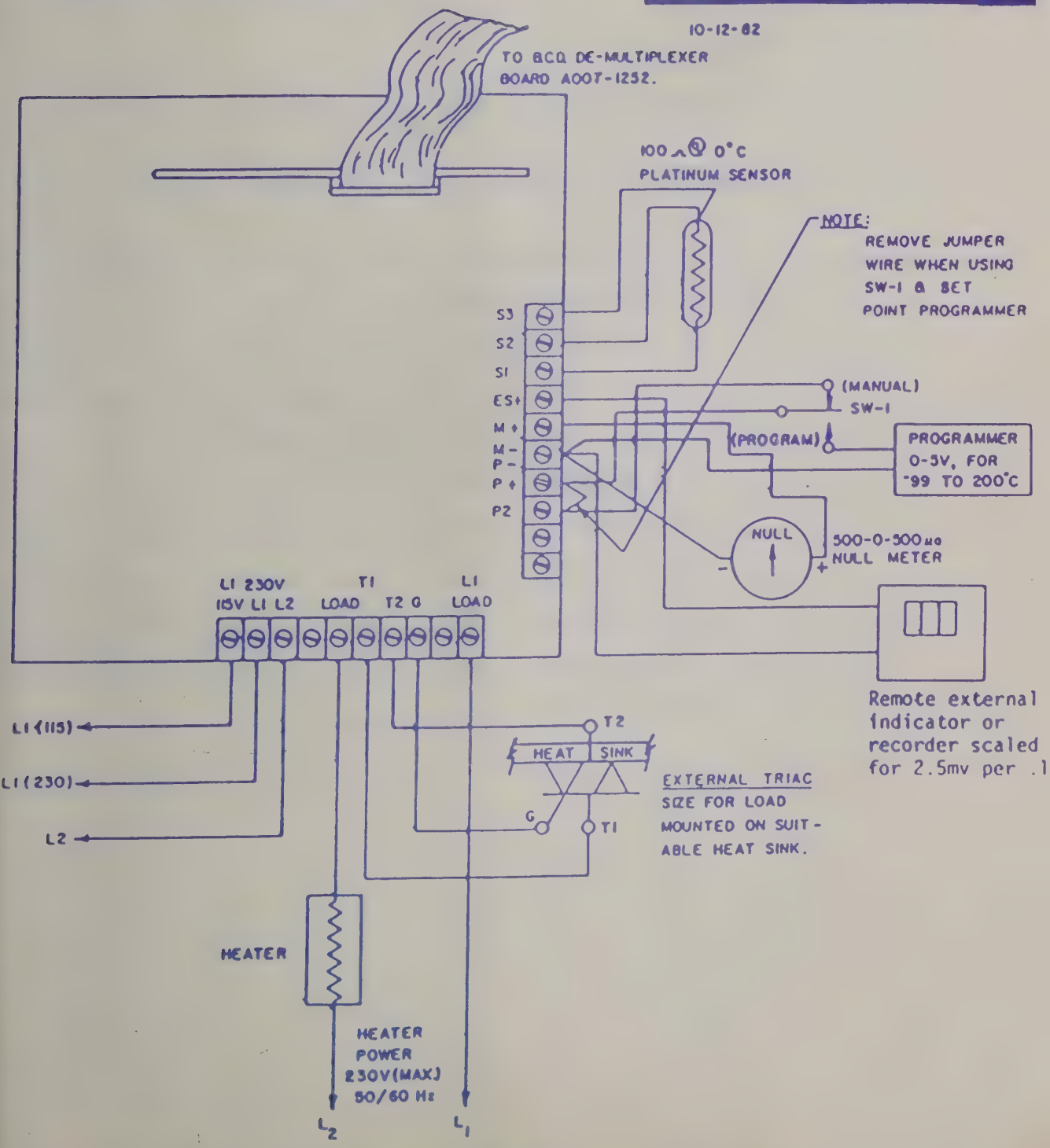
R_t = 177.14 ohms @ 200°C

Operating Ambient Temperature: 30°F to 130°F

TENNEY ENGINEERING
DATA SHEET
MODEL:
TNNY-JRCO-0001
TEMPERATURE CONTROLLER

EXTERNAL WIRING DIAGRAM

10-12-82



DATA SHEET

TENNEY ENGINEERING
MODEL: TNNY-JRCO-0001
TEMP CONTROLLER

8-23-82

FUNCTIONAL DESIGNATIONS BCD OUTPUT CONNECTOR

CONNECTOR PIN NUMBER	FUNCTIONAL DESIGNATION
1	Digital Common
2	DS-1 ; Digit Select 1 (MSD)
3	DS-2 ; Digit Select 2
4	DS-3 ; Digit Select 3
5	DS-4 ; Digit Select 4 (LSD)
6	$\overline{OR}$; Overrange
7	Q$\emptyset$; BCD Data Bit $\emptyset$
8	Q1 ; BCD Data Bit 1
9	Q2 ; BCD Data Bit 2
10	Q3 ; BCD Data Bit 3
11	EOC ; End of Conversion
12	+ 5 volt

WINONA, MINNESOTA 55987 • 1265 EAST SANBORN STREET • PHONE 507 454-5300

TNNY-JRCO-0001

TEST PROCEDURE

9-10-84

EQUIPMENT NEEDED:

1. 4½ digit D.V.M.
2. 200 ohm decade box

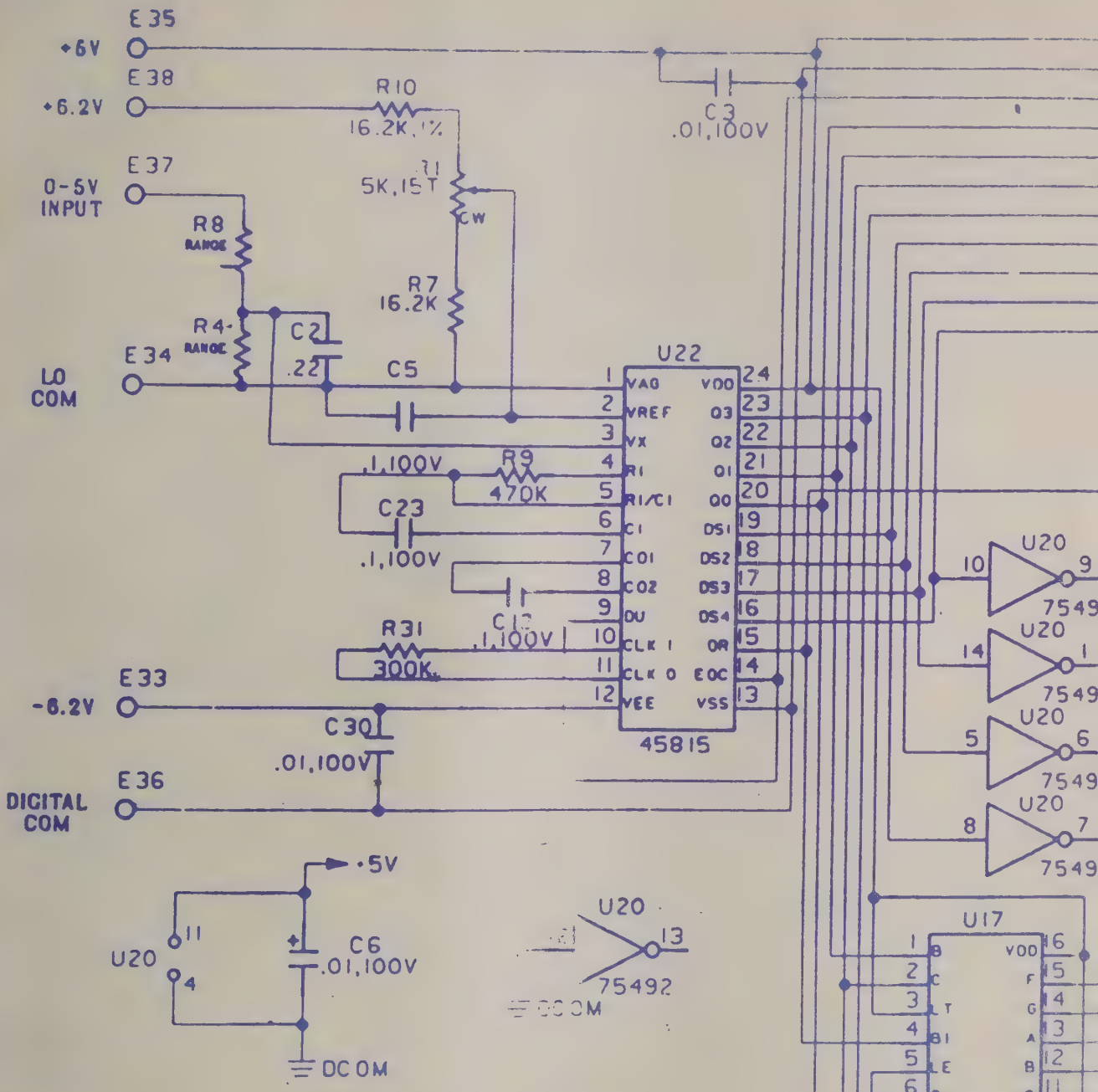
SET-UP:

1. Connect D.V.M. to D.V.M. terminals.

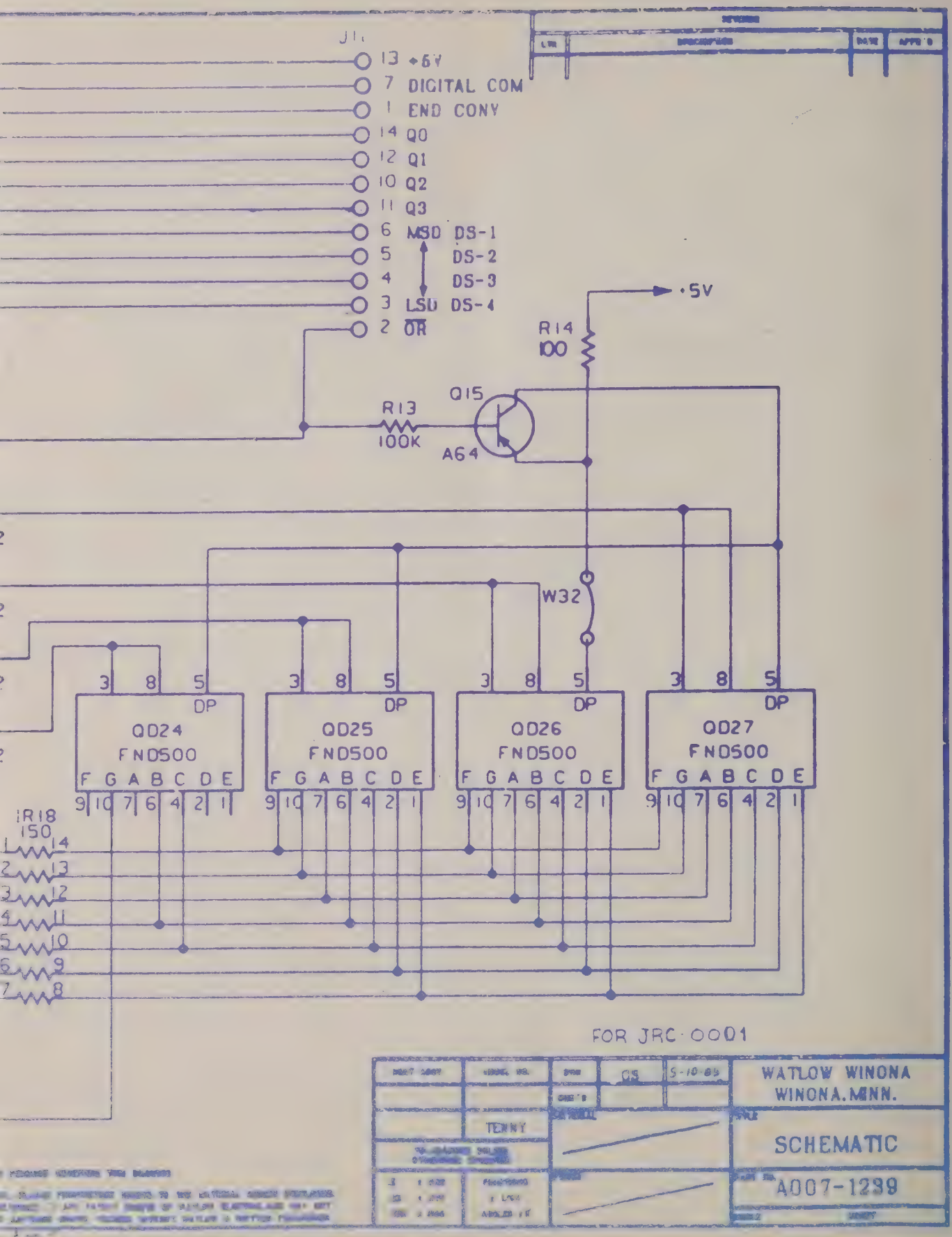
TEST PROCEDURE:

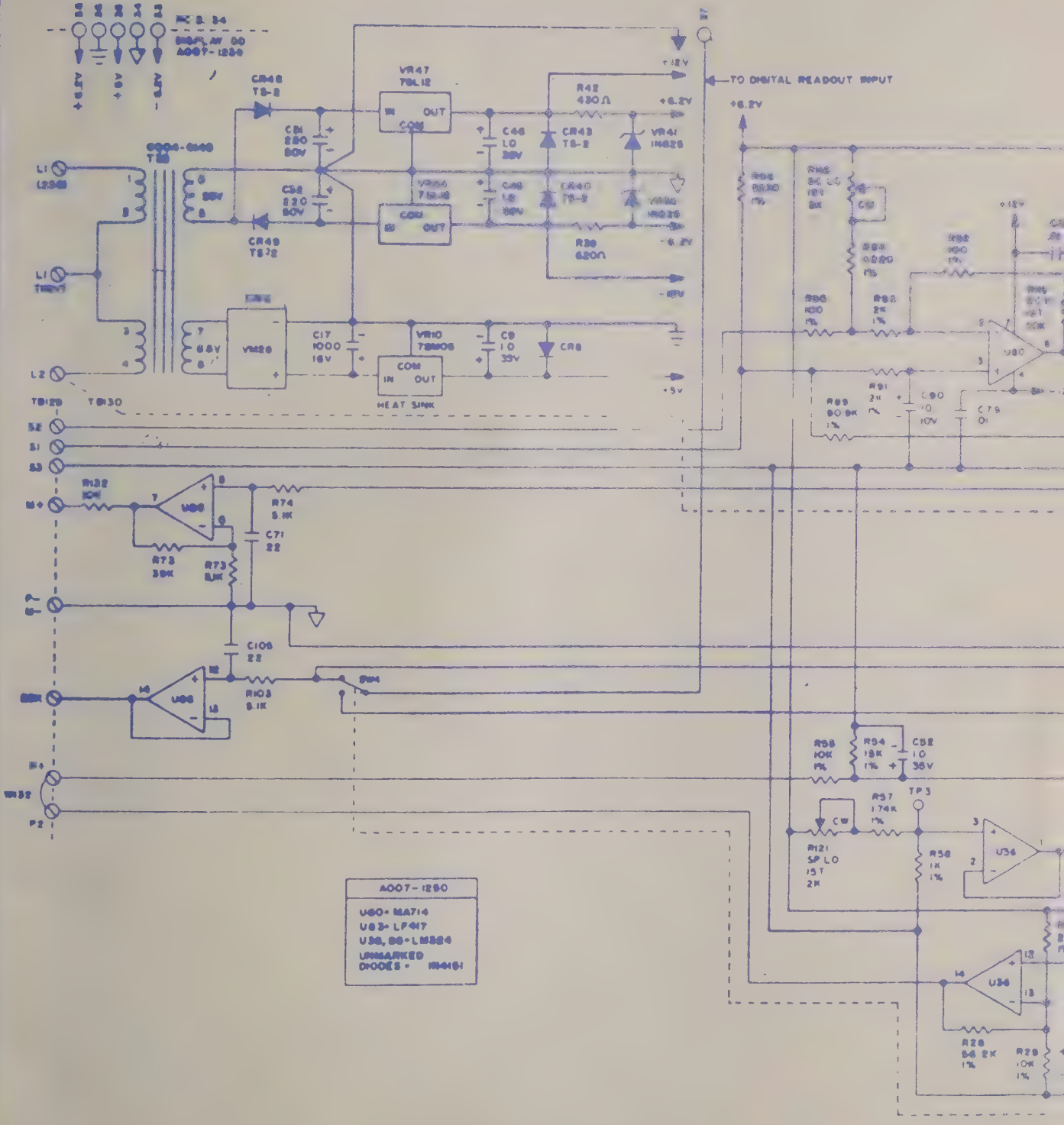
1. Connect the decade box to S1, S2, and S3, with S3 and S2 jumpered at the decade box. Turn on power to unit.
2. Set the D.V.M. to 0-20 VDC. Set the decade box to 100.00 ohms. Adjust SC Lo for 0.000V on the D.V.M. Display should read 000°C.
3. Set the decade box to 177.14 ohms. Adjust SC Hi for 5.000V ± .002V. Display should read 170°C.
4. Repeat steps 2 and 3 as required.
5. With the decade box at 177.14 and the D.V.M. reading 5V ± .002V, adjust the Hi pot on the display board for just overrange of the display. (or flickering between overrange and 199.9).
6. Check the following midpoints:

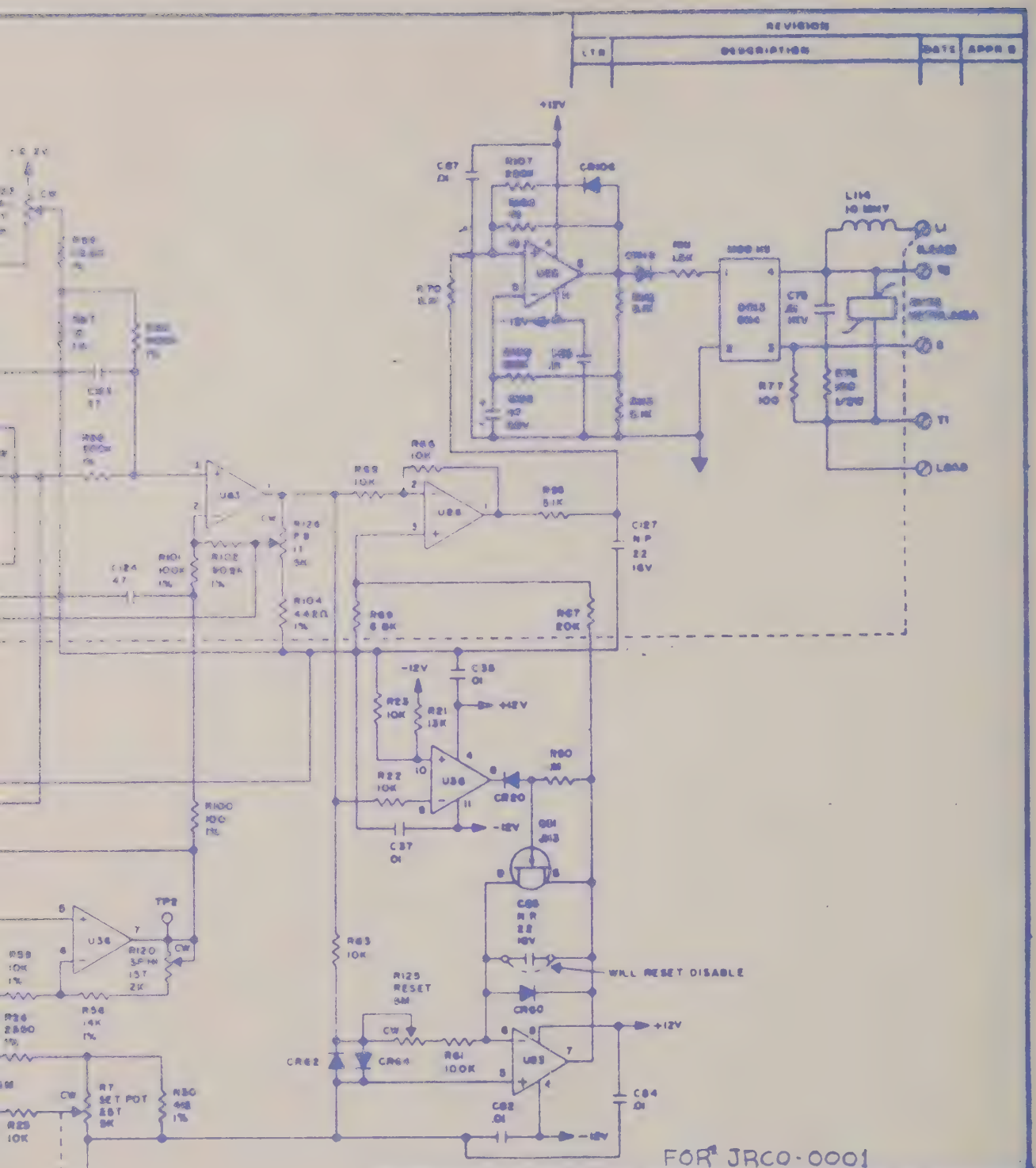
Decade Box	Display	D.V.M.
158.30 ohm	150.0 ± .8	3.75V ± .02V
119.73 ohm	50.0 ± .8	1.25V ± .02V
79.97 ohm	-50.0 ± .8	-1.25V ± .02V



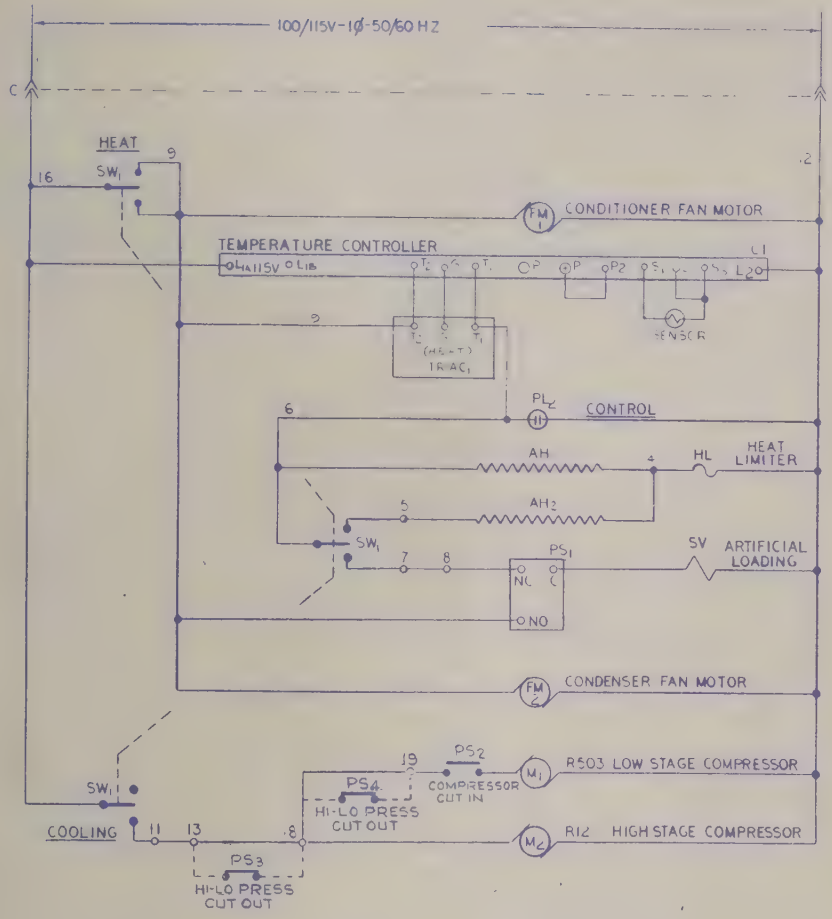
RANGE	R8	R4	R21
-100 TO 199.9 C	150K	100K	NOT USED
-160 TO 300 C	243K	10.2K	
0 TO 100 %	402K	100K	NOT USED

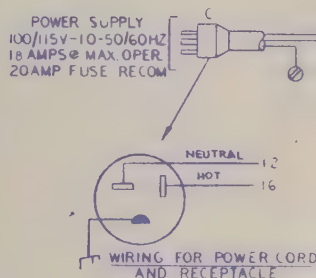

J1
13 +5V
7 DIGITAL COM
1 END CONV
14 Q0
12 Q1
10 Q2
11 Q3
6 MSD DS-1
5 DS-2
4 DS-3
3 LSD DS-4
2 OR
+5V
R14
100
Q15
R13
100K
A64
W32
QD24
QD25
QD26
QD27
FND500
F G A B C D E
3 8 5
DP
9 10 7 6 4 2 1
R18
150
1 14
2 13
3 12
4 11
5 10
6 9
7 8
FOR JRC-0001
WATLOW WINONA
WINONA, MINN.
TENNY
SCHEMATIC
A007-1299


TO DIGITAL READOUT INPUT
+12V
+6.2V
-6.2V
-15V
+5V
HEAT SINK
A007-1290
U80- MA714
U83- LF417
U36, 86- LM324
UNMARKED
DIODES - IN4151


REVISION
LTR
DESCRIPTION
DATE
APPR'D
+12V
-12V
C87 .01
R107 200K
CR104
R70 5.6K
R77 100
C78 .01 100V
LIM1 10 MHY
U
TB
TI
LOAD
R66 10K
R68 10K
R69 6.8K
R67 20K
C127 MP 22 16V
C124 47
R101 100K
R102 909K
R104 442Ω
R126 P.S 11 5K
C35 .01
R23 10K
R21 13K
R22 10K
R60 1M
CR20
C37 .01
R100 100
TP2
R120 SPAN 1ST 2K
R59 10K
R56 14K
R7 SET POT 2ST 5K
R50 49.9
R63 10K
R125 RESET 5M
WILL RESET DISABLE
CR60
CR62
CR64
R61 100K
C82 .01
C84 .01
C24 10 10V
FOR JRC0-0001
ITEM NO
PART NO
DESCRIPTION
QTY
DWN
JESSE
2-11-88
CHK'D
WATLOW WINONA
WINONA, MINN
NEXT ASSY
MODEL NO
MATERIAL
TITLE
SCHEMATIC
TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64
ANGLES ± 2°
FINISH
PART NO
A007-1250
SCALE
SHEET

ELECTRICAL SCHEMATIC





NOTES:

1. Numbers on lines identify terminals.
2. Underlining denotes nameplate located on or near equipment.
3. Coils and associated contacts bear same designation.
4. For associated wiring diagrams refer to job drawing list or fabricated assemblies summary (FAS) sheet.
5. PS1 & PS2 ARE FACTORY-SET. SEE SPEC. SHEET WHEN SPECIFIED. REMOVE [illegible]

MACHINER

TRINITY ENGINEERING, INC. UNION, N.J.

E-700-4 M

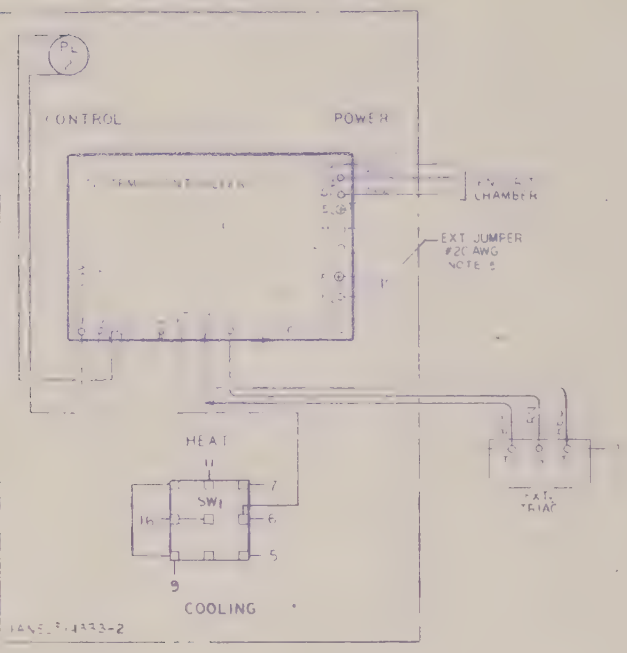
JOB NUMBER
NUMBER OF JOBS
QUANTITY PER JOB
B/M ISSUE DATE BY

DJIE007A048F010

SCHEMATIC & WRG. DIAGRAM

MODEL NO TJR16

CONTROL PANEL WIRING DIAGRAM



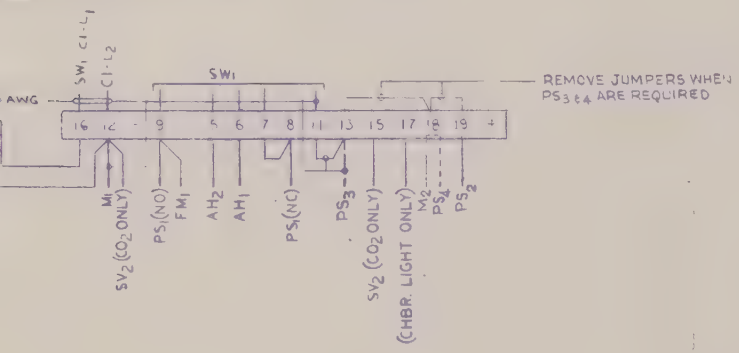
NOTE 4

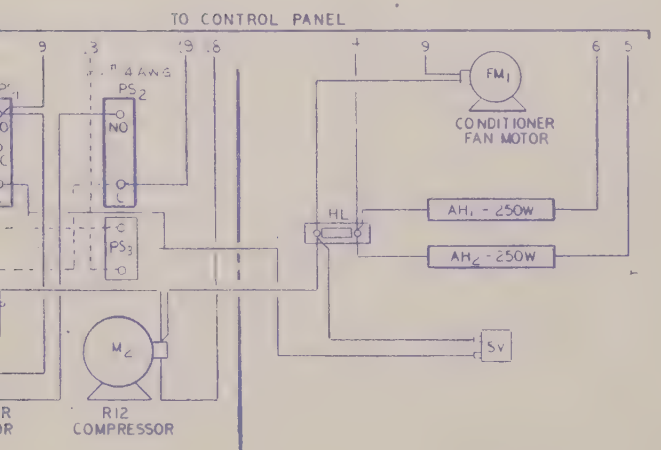
BILL OF MATERIAL

IT NO	PC NO	NO REQ'D	DESCRIPTION	TOTAL REQ'D
	C1	1	TEMP. CONTROLLER: WATLOW MODEL #[illegible]	
		1	SENSOR MINCO #S76[illegible]	
	C	1	CORD: CAROL #9 FT. CORD SET 12/3 ST. GRAY O/E 030-3 PLUG O/E ROJ 6 #NO STRIP	
	SW1	1	TOGGLE SWITCH: E-105.1-9	
	PCS	1	PILOT LIGHTS: E-106.1-1	
	HL	1	HEAT LIMITER: BUSMAN #WKV W/EYE TYPE CONNECTIONS	
	TB	1	TERMINAL BOARD: E.109.3.1.7	
			PANEL: DWG #1433[illegible]-2	
		1	RECEPTACLE: HUBBELL #5361	
		1	COVER PLATE MULBERRY #1 S-RSS	
		1	TRIAC: CANREY [illegible]	

MATERIAL CONTROL & ACCOUNTING

REQ'N. NO. & DATE	P.O. NO. & DATE	VENDOR	DATE REQ'D	DATE REC'D	TOTAL COST
			P.E.	NSE	003
			PSE	HWR	057
			P.E.	SW	004
			P.E.	LLI	003
			PSE	LHL	005
		DSØV14	P.E.	[illegible]	121
			P.E.	HRC	217
			P.E.	HRC	004
			P.E.	CCA	042





REF: E-419-4

NOTES:

1. Unless otherwise specified, all wire type TW.
2. Unless otherwise specified, all wire #16 A.W.G.
3. For associated wiring diagrams refer to job drawing list or fabricated assemblies summary (FAS) Sheet.
4. SHIP LOOSE W/ CHAMBER FOR CUSTOMER'S INSTALLATION.
5. REMOVE JUMPER WHEN MANUAL/PROG OR LOCAL/REMOTE SET POINT IS USED

LET	DATE	REVISION	BY
M		[illegible]	
L		[illegible]	
K		ADDED WIRE [illegible] REMV JUMPER LD 16 [illegible]	
J		C1-LD WIRED TO SW1 & C1-L1 WIRED TO TERM 16	
H		PLI WAS W RED TO TERM 9	2C 1-30-85
G		ADDED PS3,4	G-1-84 ALH
F		[illegible]	
E		[illegible]	
D		[illegible]	
C		[illegible]	
B		SENSOR WAS #S4140	MS 3-10 82
A		ADDED NOTE 5	

SURFACE FINISH ± TRAC. DIM ± DEC. DIM ± ANGLE DIM

TOLERANCES UNLESS OTHERWISE SPECIFIED

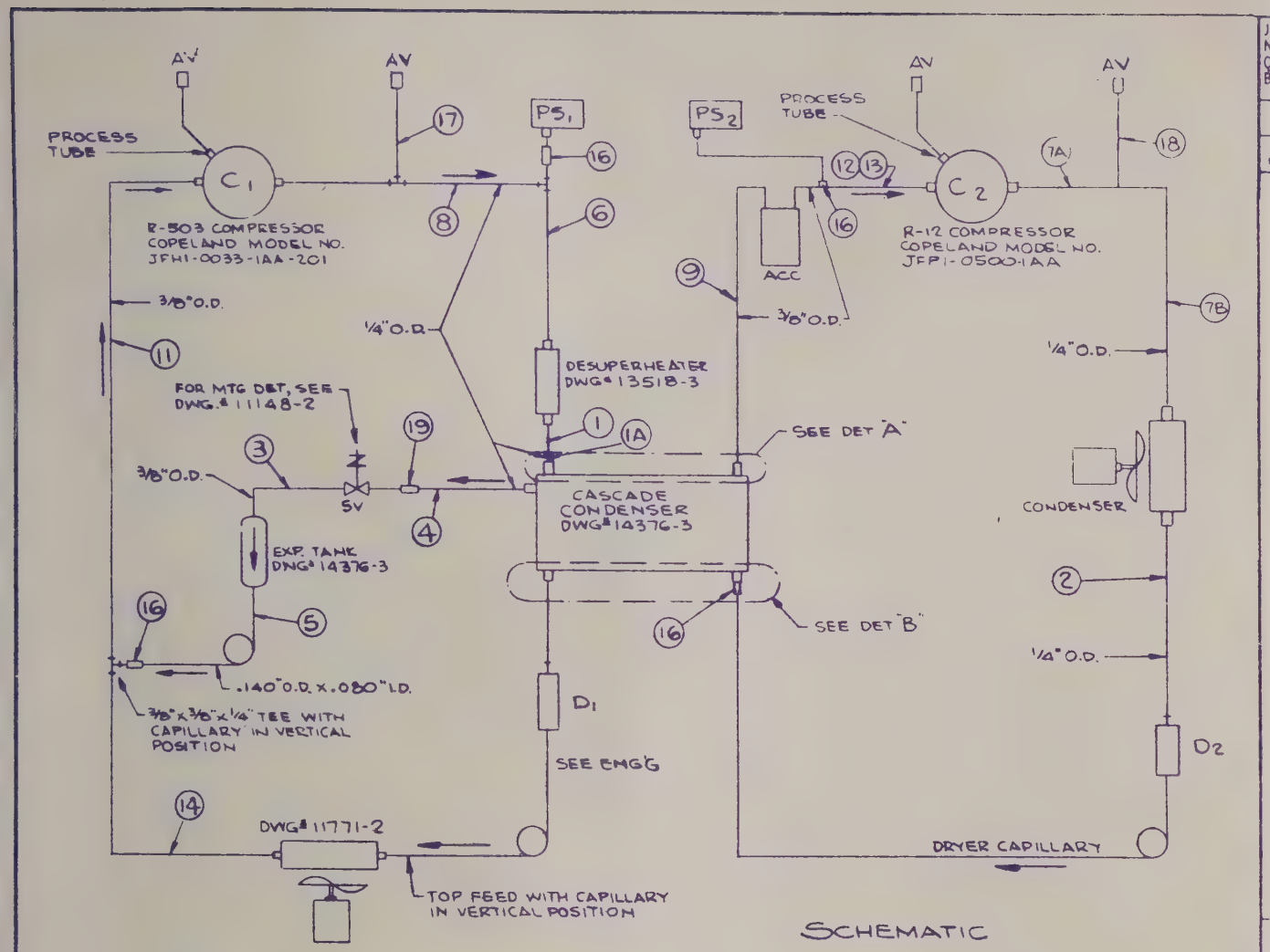
DWN. BY ZC 3-16-81 CHK'D

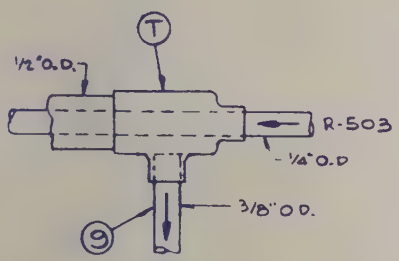
DWG ISSUE 4/2/81 APP'D.

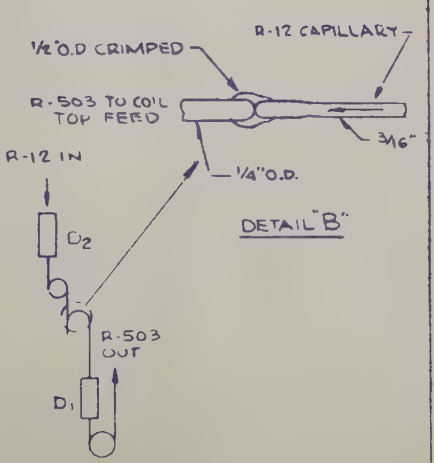
E-700-4 M

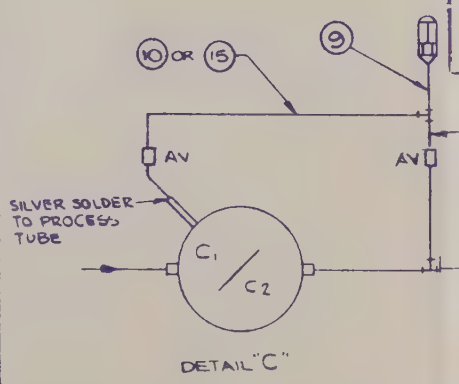
DEPT. 7

3


AV
AV
PROCESS TUBE
C1
R-503 COMPRESSOR COPELAND MODEL NO. JFH1-0033-1AA-201
17
PS1
16
8
6
3/8"O.D.
11
1/4"O.D.
DESUPERHEATER DWG# 13518-3
FOR MTG DET, SEE DWG.# 11148-2
19
1
1A
3
3/8"O.D.
SV
4
EXP. TANK DWG# 14376-3
16
5
.140"O.D. X .080"I.D.
3/8"x3/8"x1/4" TEE WITH CAPILLARY IN VERTICAL POSITION
CASCADE CONDENSER DWG# 14376-3
SEE DET "A"
SEE DET "B"
16
D1
SEE DWG'S
14
DWG# 11771-2
TOP FEED WITH CAPILLARY IN VERTICAL POSITION
AV
AV
PROCESS TUBE
PS2
12
13
C2
16
ACC
9
3/8"O.D.
7A
18
R-12 COMPRESSOR COPELAND MODEL NO. JFP1-0500-1AA
7B
1/4"O.D.
CONDENSER
2
1/4"O.D.
D2
DRYER CAPILLARY
SCHEMATIC


T
1/2"O.D.
R-503
1/4"O.D
3/8"O.D.
9
R-12
DETAIL "A"


1/2"O.D CRIMPED
R-12 CAPILLARY
R-503 TO COIL TOP FEED
3/16"
R-12 IN
1/4"O.D.
D2
DETAIL "B"
R-503 OUT
D1


10 OR 15
9
AV
AV
SILVER SOLDER TO PROCESS TUBE
C1
C2
DETAIL "C"

TENNEY ENGINEERING, INC.
UNION, N. J. PARAMOUNT, CALIF.

R-857-3 | C

UMBER
ER OF JOBS
ITY PER JOB
SUE
DATE BY

REFRIGERATION SYSTEM

MODEL NO TJR 1-22 CU. FT

BILL OF MATERIAL				MATERIAL CONTROL & ACCOUNTING					
C D	NO REQ'D	DESCRIPTION	TOTAL REQ'D	REQ'N NO & DATE	P.O. NO & DATE	VENDOR	DATE REQ'D	DATE REC'D	TOTAL COST
1	1	COMPR: COPELAND MOD NO JEH1-0033-1AA-201 115V-1Ø-60HZ W/RELAY AND START CAP.							
2	1	COMPR: COPELAND MOD. NO JEH1-0050-1AA. 115V-1Ø 60 HZ W/ELECTRICAL COMPONENTS.							
6,	1	PRESS SWITCH: PENN SERIES 210 LIMIT CONTROL MOD 210AP20X W/TERMINAL COVER, QUICK DISCONNECT TERMS, & SPDT SWITCH. SET TO CLOSE @ 280 PSIG & TO OPEN @ 240 PSIG.							
52	1	PRESS. SWITCH: PENN MOD 210AP20 SET TO CUT IN @ 18 PSIG CUT-OUT @ 30 PSIG MAX PRESS 300 PSIG W/TERM COVER							
1	1	DRIER: KENMORE ASSEMBLY PT# 30574-B-4							(B)
2	1	DRIER: KENMORE ASSEMBLY PT# 30574-B-11							
V	1	SOL VALVE: ASCO # 8321211 (115V-60HZ)							
T	1	1/2" x 1/4" x 3/8 ODS TEE MUELLER # W-40364							
EC	1	ACCUMULATOR: KENMORE MACH. PROD. - VERTICAL 1 3/8" O.D. x 7" LONG W/ (2) 3/8" O.D. SWEAT CONNS. PT# 50909-A-1							
NS	5'6"	ARMAFLEX INSULATION 1/2" I.D. x 3/8 THICK WALL							
W	4	ACCESS VALVE: 3/8" INDUSTRIES PT. NO. A31006-320							(C)

NOTES:
1) PC. NOS SHOWN IN SCHEMATIC - TUBE DETAILS ON DWG # 4870-4
2) USE TO INSULATE SUCTION LINE IN MACHINERY COMPARTMENT.
TEST PROCEDURE PER DWG. NO.

PROCESSING DATA	SYSTEMS			
	R-12	R-503		
SSURE TESTING (PSIG)		180		
C.UATION (MICRONS)	25	25		
TICAL" REFRIGERANT CHARGE COOM TEMP OF 70° TO 105° F	14 OZ	52 PSIG		

ADD 10 C.C. PENTANE TO SYSTEM CHARGE

)OR(18)

REF
R-706-3

LET	DATE	REVISION	BY
C		ADDED ACCESS VALVES	MS 2-23-77
B	11/76	PC C WA - 30574 - B-7 UNIT TO CAP TUBE	MS 11-5-76
A		REDRAWN	MS 10-5-76

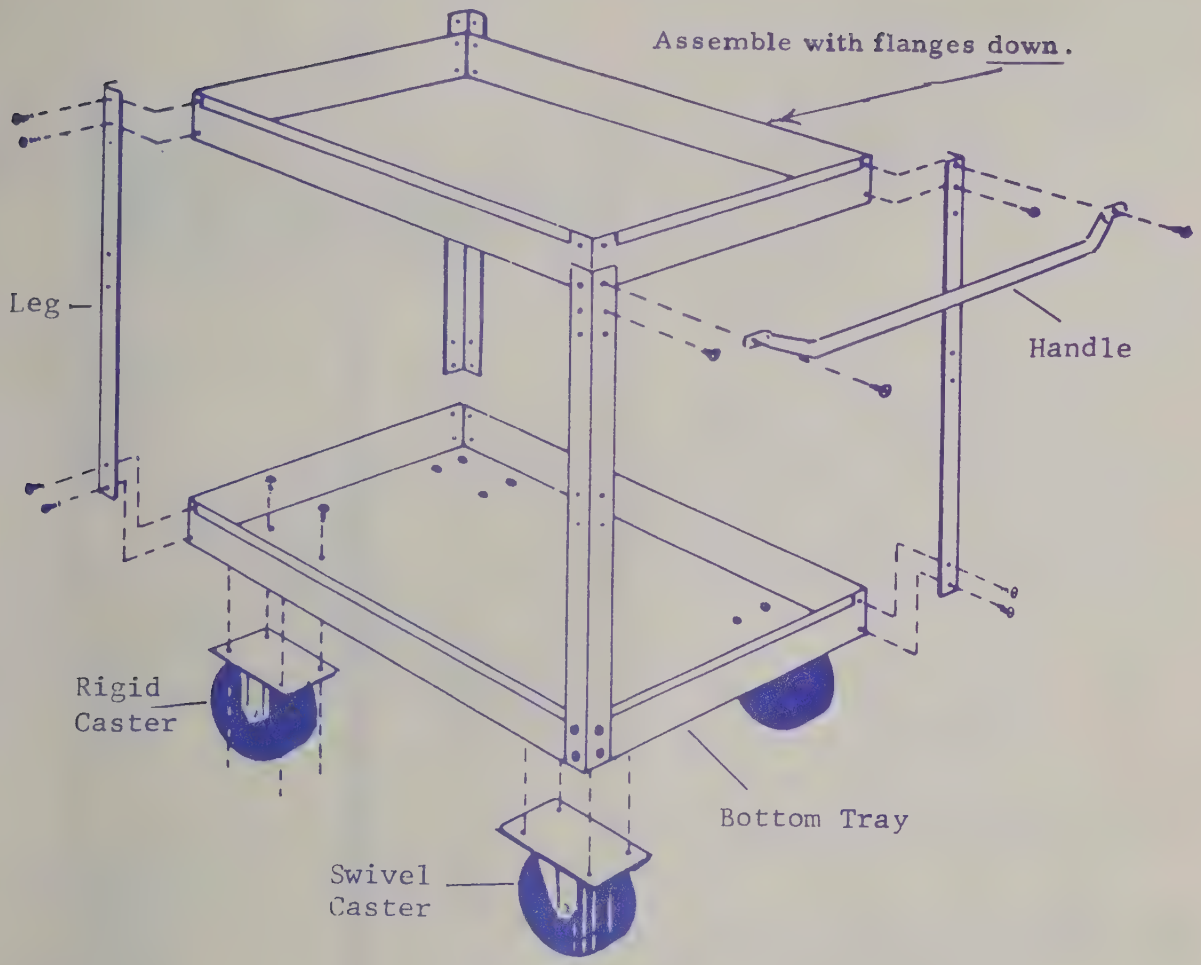
DWN BY ZC 8-24-76 | CHK'D | APP'D | DWG ISSUE

R-857-3 | C

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRAC DIM ± | DEC DIM ± | ANGLE DIM ±

DBF 0 STM

TENNEY JR CART ASSEMBLY



1. Assemble the cart on a flat, hard surface.
2. Assemble with the bottom tray flanges-up. Bolt casters to bottom tray.
3. Bolt a leg to each corner of the bottom tray. Leave bolts loose.
4. Install top tray with FLANGES DOWN.
5. Bolt handle to same end of cart as swivel casters.
6. Bolt top tray in place FLANGES DOWN.
7. With all four wheels resting firmly on flat floor, tighten all nuts.

Note: The drawing shows the top tray with flanges up. Disregard this. Install the tray with flanges down, otherwise the Tenney Jr will not fit.

Tenney ENGINEERING, INC.
The Largest and Most Experienced Manufacturer of High Technology Environmental Test Equipment
1090 Springfield Rd., P.O. Box 3142, Union, New Jersey 07083 • (201) 686-7870

Tenney
ENGINEERING, INC.

SERVICING CASCADE REFRIGERATION SYSTEMS

By
Service Department, Tenney Engineering, Inc.

This article is aimed at the serviceman already familiar with conventional refrigeration systems. Here the cascade system is described and illustrated, and suggestions are given for its service, trouble-shooting and adjustment.

• • •

TNY Tenney ENGINEERING, INC.
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Tenney ENGINEERING, INC.

ENVIRONMENTAL TEST EQUIPMENT

The Largest and Most Experienced Manufacturer of High Technology Environmental Test Equipment

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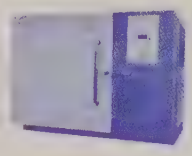
BENCHTOP TEMPERATURE CHAMBERS

Work space:
1¼ and 5 cubic feet.
Temperature range:
−80°C to +200°C



Bulletins 108 and 123

BENCHTOP TEMPERATURE-HUMIDITY CHAMBERS

Workspace:
3 and 5 cubic feet
Temperature range:
−73°C to +200°C
Humidity capabilities:
20% RH to 98% RH

Bulletins 101 and 123

TENNEY SERIES HIGH-LOW TEMPERATURE AND TEMPERATURE HUMIDITY TEST CHAMBERS

Workspace:
6 cubic feet
64 cubic feet
Temperature range:
−80°C to +200°C
Humidity: Optional

Bulletins 104 and 144

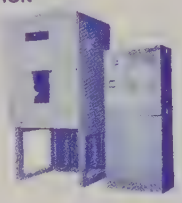
TH & T SERIES MODERATE RANGE TEMPERATURE-HUMIDITY CHAMBERS

Workspace:
27 cubic feet and
65 cubic feet
Temperature range:
Low to −18°C
High to +93°C
Humidity: Optional

Bulletin 139

MIL-STD 781 AGREE TEMPERATURE- VIBRATION CHAMBERS

Size:
Available in
sizes for mating with vibrator units having table tops from 4 square feet to 40 square feet
MicroTenn Standard



Bulletin 105

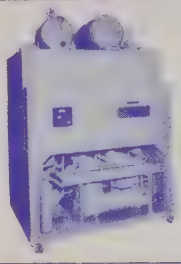
TENNEYSTRAT ALTITUDE- TEMPERATURE CHAMBERS

Workspace:
3.2 cubic feet thru
64 cubic feet
Temperature range:
−73°C to +200°C
Altitude: to 200,000 feet
Humidity: Optional

Bulletin 141

LOW TEMPERATURE PROCESS EQUIPMENT

Packaged
Refrigeration Systems
Temperature range:
Low to −73°C
High to +121°C



Bulletin 114

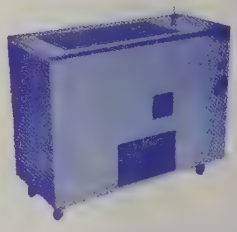
VIBRATION/ TEMPERATURE CHAMBERS

Workspace:
Standard from
5 cubic feet to
64 cubic feet
Temperature range:
−73°C to +200°C
Humidity: Optional

Bulletin 102

MULTI-RANGE PRECISION TEMPERATURE BATHS

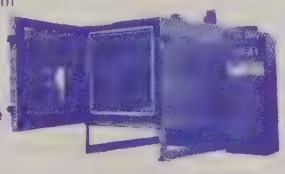
Workspace:
One gallon and
nine gallon
Temperature range:
−73°C to +120°C



Bulletins 107 and 125

CERT SYSTEMS

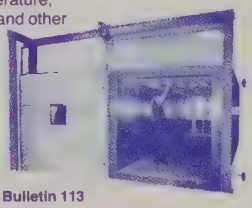
Combined Environment Reliability Testing Systems provide temperature, humidity, altitude, random vibration and cooling air simulation. Permits simulation of mission profile environments.



Bulletin 134

WALK-IN ROOMS

For burn-in, temperature, humidity, altitude and other controlled environment testing. Custom-engineered in unitized or semi-unitized packages as well as modular panels.



Bulletin 113

THERMAL VACUUM SPACE SIMULATORS

Workspace:
Standard 1½ feet to 6 feet diameters
Vacuum capability:
to 2×10^{-8} Torr.
Temperature range: From
−196°C to +177°C

Bulletin 120

MECHANICALLY REFRIGERATED THERMAL SHOCK CHAMBERS

Workspace:
3, 5 and 8 cubic feet
Temperature range:
Top compartment
+200°C
Lower compartment
to −73°C
Center compartment
ambient optional
DigiTennStandard

Bulletin 121

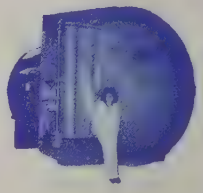
VACUUM CHAMBERS AND VACUUM OVENS

Workspace:
4 cubic feet thru
27 cubic feet
Temperature range:
to +150°C
Vacuum capability:
to 148 microns
(200,000 feet)

Bulletin 110

AUTOCLAVE SYSTEMS

Sizes:
Small laboratory models to large production units
Temperature range:
+400°C
Pressure to 800 psig.
Vacuum: Optional



Bulletin 122

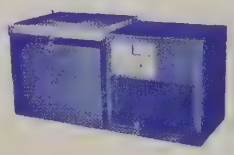
MICROTENN®

Microprocessor Programmer-Controller automatically signals chamber to perform programs entered via the keyboard or by the Microcassette transport. Computer interfaces are available.

Bulletin 137

TENNEY SUB-ARCTIC INDUSTRIAL CABINETS AND COLD STORAGE CHESTS

Workspace:
6 cubic feet thru
12 cubic feet
Temperature range:
Low to −84°C
High to +177°C



Bulletin 115

BURN-IN CHAMBERS

Size and number of doors may be specified to meet any burn-in requirement
Typical temperature range:
0°C to +60°C

Bulletin 133

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Introduction

This information is written to help the refrigeration serviceman repair and trouble-shoot low temperature cascade systems. It is assumed that the reader is familiar with standard refrigeration practice and is interested in the special techniques applicable to cascade systems.

History

Prior to the development of low boiling point refrigerants such as R 13 (-114°F) and R 503 (-127°F), reaching ultra low temperatures via mechanical refrigeration was difficult. R 22 was used down to -80°F, but its system had serious drawbacks. Large and cumbersome, the machinery was subject to the many troubles which afflict a compound system operating at suctions as low as 23" of vacuum.

The modern cascade system can reach as low as -120°F with suction pressures of 0 psig or higher. Compact, serviceable, and reliable, today's cascade system is found on thousands of environmental test chambers.

How It Works

Two types of cascade systems are popular: expansion valve and capillary tube. Both are discussed in the text, and capillary systems are shown in the schematics which comprise part of this paper.

Refrigerants with low boiling points have correspondingly high condensing pressures at normal ambients. They cannot be liquefied by conventional air or water cooled condensing units. Therefore, low temperature refrigerants are condensed by a separate refrigeration system called "the high stage". The sole job of the high stage in most cascade systems is to condense low stage refrigerant.

High Stage

The high stage is a conventional single stage system having a compressor, air or water cooled condenser, expansion valve, and evaporator. The evaporator is the cascade condenser, serving the low stage. Modern systems use R 502 in the high stage, making -50°F refrigerant temperature possible at 0 psig suction pressure.

Low Stage

The low stage is charged with refrigerant in vapor phase only, to a specified gauge pressure. When the low stage is idle, with all components

stabilized at 70°F, it will contain no liquid refrigerant. When the system is activated, the low stage compressor will pump hot gas through the discharge line to the desuperheater. The desuperheater, air or water cooled, removes some heat from the refrigerant gas, lightening the heat load on the cascade condenser. Leaving the desuperheater, the gas passes through an oil separator, then flows to the cascade condenser where it is liquefied by heat exchange with high stage refrigerant. After passing through a drier, cold low stage liquid refrigerant flows to the expansion valve.

Expansion Valve

The expansion valve meters refrigerant to the cooling coil located in the workspace. In the coil, refrigerant evaporates, absorbs heat, then returns to the compressor as a cold gas.

Frosted Lines Are Typical

A low stage characteristic is frosted liquid and suction lines. In a normal cascade system, the liquid line is always below +32°F. The suction line, returning from a -100°F evaporator, assuming 15° superheat, will also be far below freezing.

Expansion Tank

An expansion tank is provided to add volume to the low stage. Added volume permits the charging of additional refrigerant without increasing the standby or charging pressure beyond workable limits. Refrigerant gas is sucked out of the expansion tank during system operation: It is metered through a constant pressure valve, capillary tube, or needle valve, the valve or restriction regulating rate of gas entry into the system.

Load Limit Valve

Connected between expansion tank and discharge side of the low stage, a load limit valve acts as a relief device. It bleeds down or dumps gas into the expansion tank when low stage discharge pressure reaches valve setting, usually 185 to 240 psig. High pressures are generated when the low stage starts up but the load limit valve, acting as a relief, prevents the compressor from cycling on and off in response to signals from the high pressure cutout.

Leak Testing

Loss of refrigerant is the most common cause of refrigeration failure. Because of temperature extremes felt by its metal parts, the cascade system is particularly susceptible to leaks.

Check the entire system with an electronic leak detector. If the system is empty or at low pressure, boost pressure to 200 psig with inert gas (not oxygen!) diluted with a percentage of R 12. Test again.

A leak check while the system is at low temperature, -80°F or colder, is a must. Tighten and leak check expansion valve flanges, superheat adjustment caps and other mechanical joints while at low temperature.

You may use a halide torch to locate large leaks, but make your final test with the more sensitive electronic leak detector. This is especially important on the low stage. The low stage is gas charged with a relatively small quantity of refrigerant. Because of this, small leaks can quickly incapacitate the system.

Testing By Static Charge

One advantage of a gas charged system is that its tightness can be checked by periodic observation of static or standby pressure. You must read the pressure with all parts of the system at ambient temperature. This is important. The unit must be shut down at least 24-hours before a static pressure reading is taken. To eliminate the possibility of cooling the cascade condenser via the high stage pump-down cycle, all power to the unit must be off during the shut down period.

When reading static pressure, consider ambient temperature. Most static charge data are for a 70°F ambient, but pressure will decrease 5 psig for each 10°F decrease in temperature. Due to a large system's considerable thermal mass, several days may be required for all components to completely stabilize at a particular ambient.

Evacuation

Granted, refrigerants 13 and 503 are expensive, but there are times when charges must be bled off. A contaminated system must be cleaned and evacuated regardless of refrigerant expense.

If there is a possibility that moisture, non-condensibles or the wrong refrigerant contaminate a system, blow the charge and evacuate.

Select a two-stage pump capable of pumping the system down below 200 microns, and connect an appropriate gauge to read system pressure. The ordinary compound refrigeration gauge is inadequate, but a thermocouple gauge is ideal. Evacuating a leaky system is an exercise in futility; therefore, make sure the system is absolutely tight before beginning evacuation.

Charging a Low Stage

1. Do not charge liquid into the low stage.

2. Do not charge the system when it is below room temperature.

3. Do not use charging hoses on R 13 or R 503. Cylinder pressure exceeds 500 psig.

4. Never charge the unit when it is running.

As you will note from the above, low stage charging procedure differs from the conventional method. Correct charging pressure will be noted on the equipment nameplate or in the instructions. Remember, it is important that you charge by pressure, not by volume of refrigerant.

Use 1/4" copper tube between refrigerant cylinder and system. Open the cylinder valve very slowly. Charge into the suction side while closely watching the discharge gauge. When correct pressure is reached, shut off the refrigerant cylinder valve, allowing the system to equalize for 10 to 15 minutes. If the pressure drops, again crack open the cylinder valve, slowly raising the pressure. Always take enough time: Systems with expansion tanks connected by a capillary tube or restrictor valve may need several minutes for gas pressure to equalize.

Keep the refrigerant cylinder upright when charging. Above all, be careful! Don't over-pressurize. Disconnect the cylinder immediately that charging is complete. A leaky cylinder valve could continue to bleed high pressure refrigerant into the system, possibly causing it to rupture. Don't take chances; the saturation pressures of low temperature refrigerants are extremely high.

Drawing No. 1

A small cascade system, using two 1/3 hp hermetic compressors is delineated in this schematic. The high stage is charged with 14 oz. of R 12 the low stage carrying a static pressure of 52 psig at room temperature. 10 c. c. of pentane is added to the low stage charge to help prevent waxing of the lubricant at extremely low temperatures.

Flow of refrigerant in the high stage is from compressor C2 to the air-cooled condenser. As a liquid, R 12 flows from condenser to capillary tube drier assembly D2 which meters refrigerant to the cascade condenser. After evaporating in the condenser assembly, which is a heat-exchanger, R 12 returns to the compressor C2 via the suction line and accumulator ACC.

Function of pressure switch PS2 is to energize the low stage compressor after the high stage has started. Purpose of the arrangement is to prevent both compressors from hitting the power line at the same instant.

Refrigerant flow in the low stage is from the compressor through the desuperheater to the cascade condenser where gaseous R 503 is cooled and liquefied. Capillary tube assembly D1 meters R 503 into the evaporator 11771-2 which cools the chamber. From the evaporator, refrigerant returns to the compressor via the suction line.

Excess refrigerant is stored in the expansion tank and is fed back to the system on demand through capillary tube 5.

Solenoid valve SV serves two purposes: On a cooling "off" cycle it functions as an artificial loading valve, partially by-passing the evaporator and reducing cooling capacity. Refrigeration is modulated through this valve, not by cycling of the compressors. Valve SV also functions as a dump valve. Responding to signals from pressure switch PS1, it opens when head pressure exceeds a predetermined pressure setpoint, typically 280 psig.

Drawing No. 2

The refrigeration system shown is similar to that described on drawing no. 1. Hot gas from high stage compressor C2 is used to heat the chamber door mullion before entering air cooled condenser CON/20. Switch PS2 energizes the low stage compressor, and switch PS1 operates the dump valve SV14, that valve also being under command of the temperature controller which uses it to modulate refrigeration capacity.

Drawing No. 3

When operated in cascade mode, the system shown on this schematic functions essentially the same as the two systems previously described. R 502 flow is from compressor C2, through mullion heater to condenser, then through cap tube assembly D/9 to the cascade condenser. Return flow is via the suction line and accumulator ACC/21. Flow of R 503 is from compressor through cascade condenser and cap tube D/8 to the low temperature coil, then back to the compressor through the suction line. Valve SV14 functions as modulating (artificial loading) and dump valve in the usual manner.

Low stage R 503 compressor C1 is shut down when the system operates in single stage mode for "ambient" cooling and workspace dehumidification. R 502 flow is then as follows:

After being liquefied in the condenser CON/20, refrigerant flows to solenoid valves SV1 and SV4. When the dry bulb temperature controller calls for cooling, it opens valve SV1, admitting refrigerant to the ambient cooling coil. After evaporating, the R 12, as a cool gas, returns to the compressor via evaporator pressure regulator AEV/6 and the suction line. Purpose of the regulator AEV/6 is to prevent the ambient coil from operating too cold, a condition which is undesirable when the chamber is being operated at high humidity.

When the wet bulb controller or humidity control signals for decreased workspace humidity, control voltage is applied to solenoid valve SV4. Refrigerant is admitted to the dehumidification coil, returning to the high stage compressor via the suction line.

Capillary tube D/9 which feeds the cascade condenser is not valved off while the high stage operates in "ambient" single stage configuration. It functions as a by-pass so that when solenoid valves SV1 and SV4 are both closed there remains a path through which refrigerant can circulate. On most larger systems, this line is valved off, and other forms of by-pass are provided.

CASCADE REFRIGERATION GLOSSARY

Cascade Condenser is the high stage system's evaporator and the low stage system's condenser. Can be either tube in tube with the low stage refrigerant in the outside tube or tube in shell with the low stage refrigerant in the shell.

Desuperheater can be either air or water cooled. Its purpose is to remove some heat from the low stage discharge gas and thereby lighten the load on the cascade condenser. On air cooled units, a few passes at the top of the high stage condenser are used as the desuperheater. Water cooled desuperheaters are either tube in tube or shell in tube. The water flow is usually in series with the high stage condenser.

Low Stage is the low temperature stage or system that cools the chamber or work space evaporator. Common low stage refrigerants are R 13, R 503, and R 14. Low stage refrigerants have low boiling points and correspondingly low condensing temperatures.

High Stage usually R 12, R 502, or R 22, is used to cool the low stage condenser. Some high stage systems are used, as a separate function, to provide moderate cooling for the chamber work space.

Load Limit Valve is sometimes called dump or blow down valve. Located between the discharge side of the low stage and the expansion tank, this valve opens, allowing gas to flow into the tank, thereby reducing head pressure.

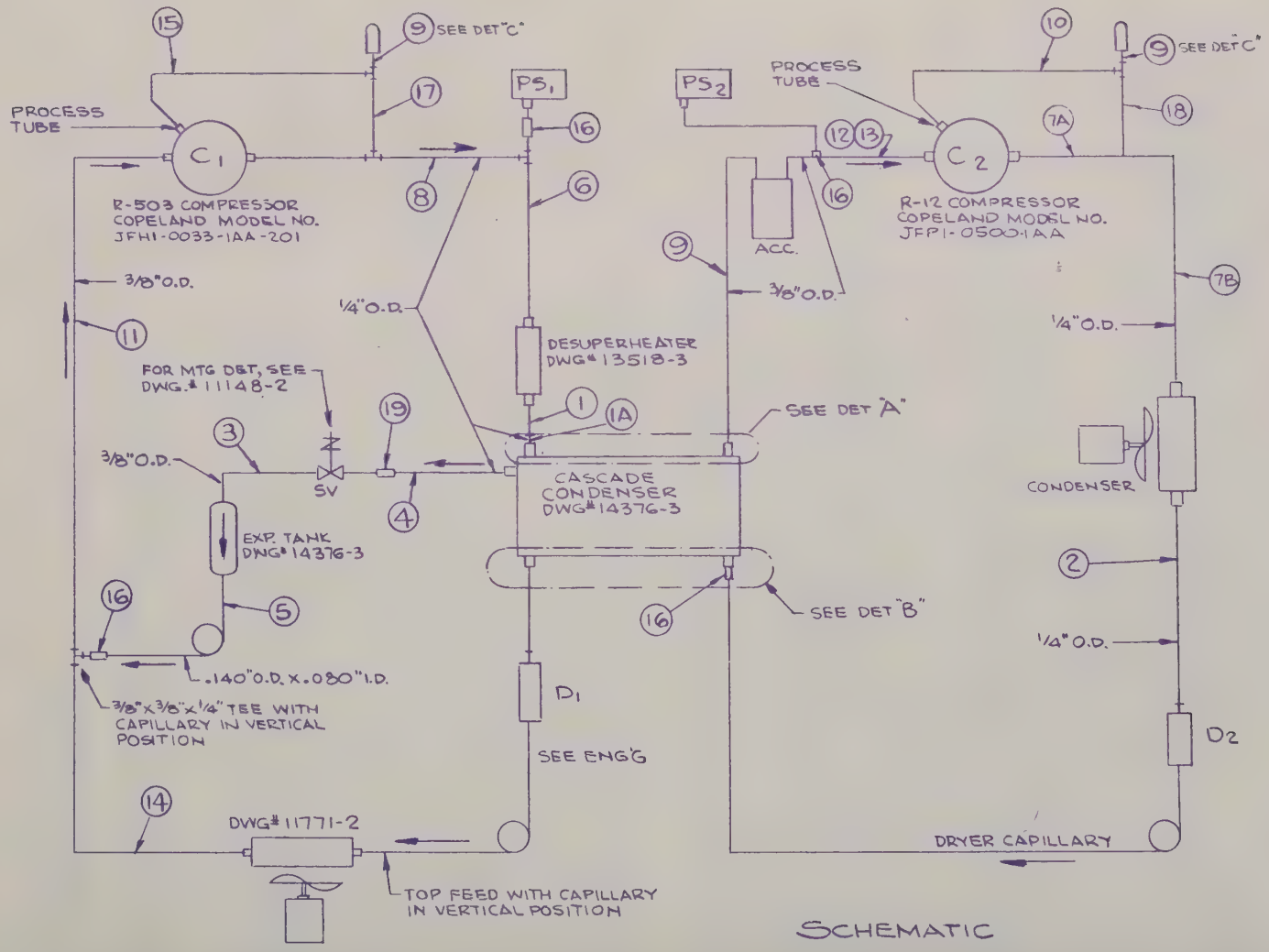
Expansion Tank is used in the low stage to provide additional system volume. It allows the use of sufficient refrigerant charge, while maintaining reasonable standby or static pressure.

Static Charge is the gauge pressure indicated in the low stage. The equipment manufacturer will designate proper static or standby pressure for a particular unit. A typical nameplate will specify low stage R 13, 7 lbs. static 120 psig. This means that if you add R 13 gas to an evacuated unit, until system pressure is 120 psig, you will have removed 7 lbs. from your cylinder.

Pull Down Time is the length of time required to lower air in the chamber work space from ambient, a nominal 70°F, to desired low temperature. The temperature is measured at the discharge of the fan. Air is normally drawn over the evaporator and discharged into the work space.

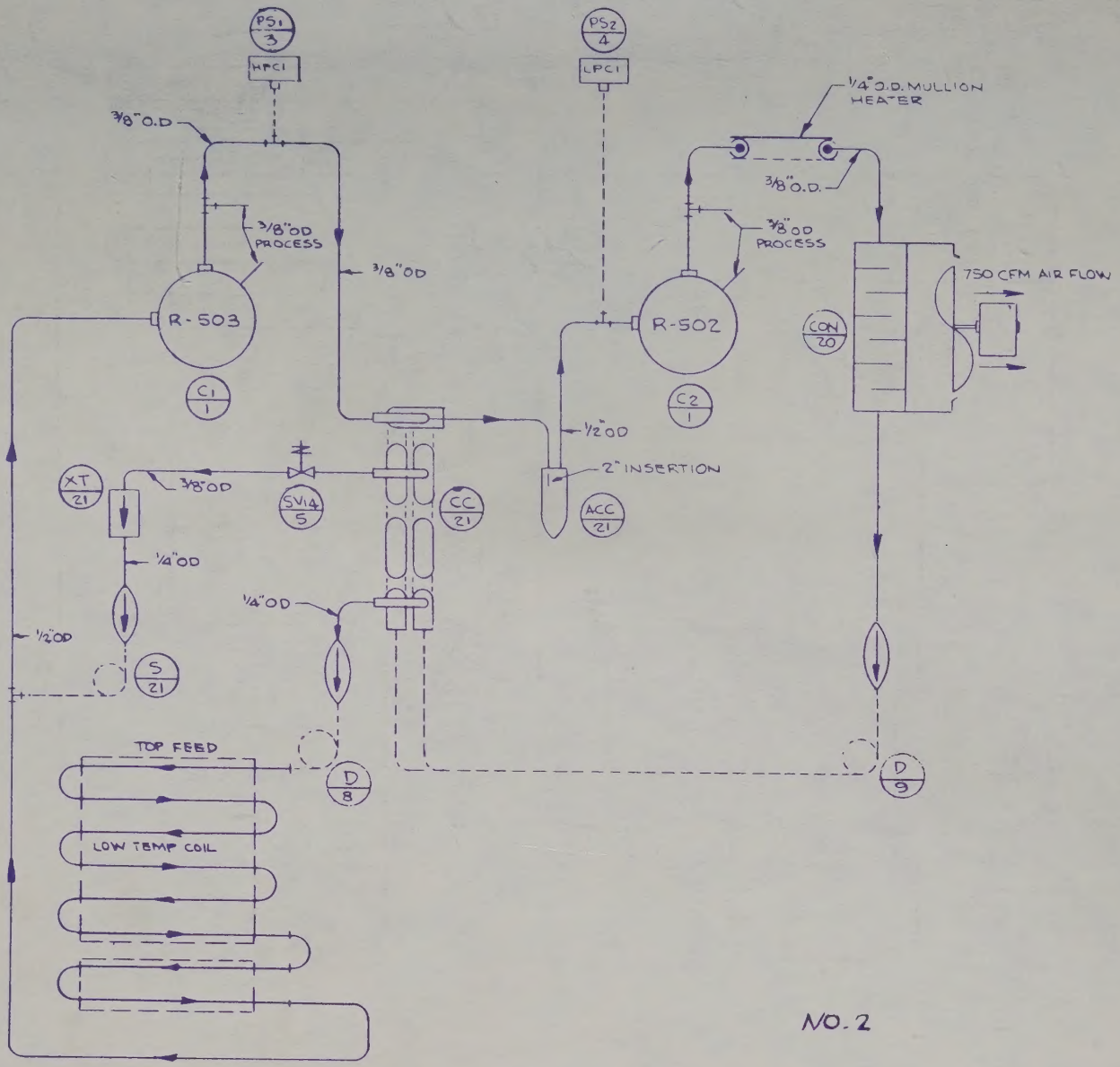
Sub Zero Cooling is the term used to describe the mode of cooling wherein the low stage refrigerant is used to cool the work space.

Ambient Cooling describes the high stage unit being used to cool the work space via its own evaporator.

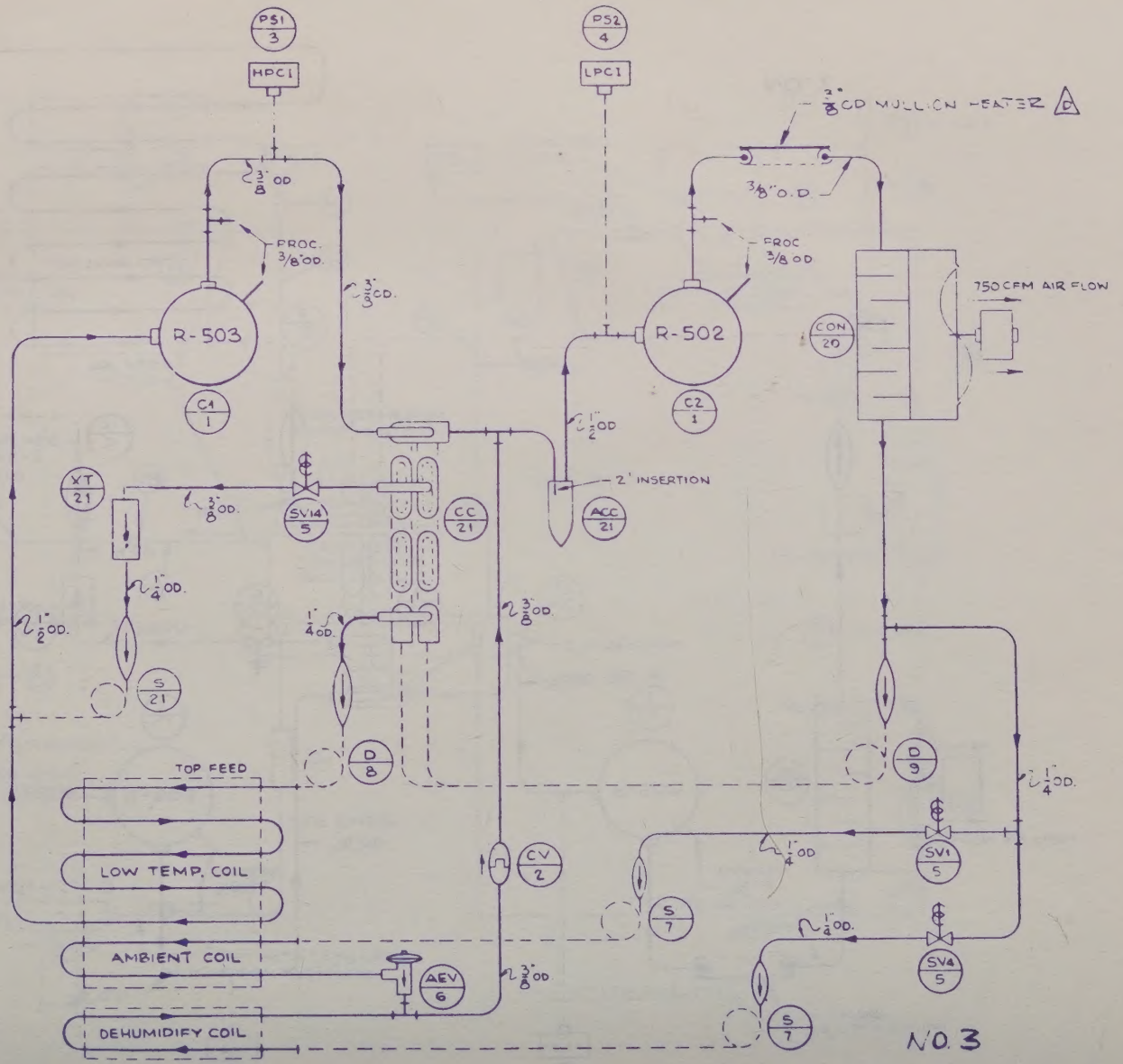


SCHEMATIC

NO. 1


PS1
3
HPCI
PS2
4
LPCI
1/4" O.D. MULLION HEATER
3/8" O.D
3/8" O.D.
3/8" OD PROCESS
3/8" OD PROCESS
3/8" OD
R-503
R-502
750 CFM AIR FLOW
CON
20
C1
1
C2
1
1/2" OD
2" INSERTION
XT
21
3/8" OD
SV14
5
CC
21
ACC
21
1/4" OD
1/4" OD
1/2" OD
S
21
TOP FEED
D
8
D
9
LOW TEMP COIL

NO. 2


PS1 3
HPCI
PS2 4
LPCI
3/8" OD
PROC. 3/8" OD.
3/8" O.D.
PROC 3/8 OD
3/8" CD MULLION HEATER D
750 CFM AIR FLOW
R-503
C1 1
R-502
C2 1
CON 20
3/8" OD.
1/2" OD
2" INSERTION
XT 21
SV14 5
CC 21
ACC 21
1/4" OD.
1/2" OD.
S 21
D 8
D 9
TOP FEED
LOW TEMP. COIL
CV 2
SV1 5
S 7
AMBIENT COIL
AEV 6
SV4 5
DEHUMIDIFY COIL
NO. 3

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